CREATING THE NEW WEALTH: NATIONAL RESEARCH AND DEVELOPMENT FUNDING IN THE 1990s

HEARINGS

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

APRIL 11, 12, 1989

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CONTENTS

WITNESSES

	Page
April 11, 1989:	
Dr. William F. Brinkman, Executive Director, Research, Physics, AT&T Bell Laboratories, Murray Hill, New Jersey	12
Dr. Arnold H. Packer, Senior Research Fellow, Hudson Institute, Indianapolis, Indiana	33
Dr. Rustum Roy, Director, Science, Technology and Society Program, Pennsylvania State University, University Park, Pennsylvania	81
Dr. William R. Graham, Director, Office of Science and Technology Policy, Executive Office of the President, Washington, DC	106
Dr. Victor L. Peterson, Director of Aerophysics, Ames Research Center, NASA, Moffett Field, California	126
Dr. Leon M. Lederman, Director, FERMI National Accelerator Laboratory, 1988 Nobel Laureate in Physics, Batavia, Illinois	148
April 12, 1989:	
Dr. Ralph E. Gomory, Senior Vice President, Science and Technology, IBM Corporation, Armonk, New York	171
Dr. Herbert H. Woodson, Dean of Engineering, University of Texas, Austin, Texas	205
Dr. Pravine Chaudhari, Co-Chair, Academy of Sciences Study "Materials Science and Engineering for the 1990s," and Vice President, Science, Thomas J. Watson Research Center, IBM Corporation, Yorktown Heights, New York	231
Dr. Saul K. Fenster, President, New Jersey Institute of Technology, Newark, New Jersey	251
Dr. Arnold Speert, President, William Paterson College, American Association of State Colleges and Universities, Wayne, New Jersey	270

CREATING THE NEW WEALTH: NATIONAL RESEARCH AND DEVELOPMENT FUNDING IN THE 1990s

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TUESDAY, APRIL 11, 1989

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The committee met, pursuant to call, at 9:40 a.m., in room 2318, Rayburn House Office Building, Hon. Robert A. Roe [chairman of the committee] presiding.

Present: Representatives: Roe, Scheuer, Walgren, Volkmer, McCurdy, Mineta, Valentine, Skaggs, Schneider, Boehlert, Ritter, Packard, Slaughter, Smith (TX), Shays, Rohrabacher, and Schiff.

Also present: Dr. John Holmfeld, Science Policy Staff, and Christopher Wydler, Republican Legislative Director.

The CHAIRMAN. The committee will come to order.

Last week, this committee initiated an important series of hearings focused on the theme, What should we as a nation do now, today, to maintain U.S. leadership in science, space, technology, and education in the decade of the 1990's? We are specifically interested in United States technology, its sources, and its uses.

The underlying reason for our focus on the Nation's leadership in technology is important to every American, for it is only if we maintain that leadership in technology that we can maintain the standard of living of the American people, and it is only through technological innovation that we can generate the advances in material wealth that ultimately provide us with the standard of living we must have.

In the initial hearing last week, we examined what our policies for technology transfer to allied nations should be. We based those hearings on the currently significant case of the FSX fighter plane and our technology cooperation with Japan, and we were especially interested in the effects of such technology transfers on America's longer-term ability to maintain its technological leadership and competitiveness.

The hearings today and tomorrow deal with another significant aspect of that same question: What must we do to ensure that the Nation's strength in basic and applied research, on which so much of our technological innovation is based, is maintained? And what must be done to ensure that we do a better job of translating the findings of basic and applied research into products that are commercially successful in both the domestic and world markets?

We know that it is chiefly through technological innovation that we can maintain today's leadership. We cannot lower the wages of American workers, with the resulting lowering of our standard of living, to achieve that end. The idea that we should seek to match the lower wages of some of our international competitors has been decisively rejected by the American people and by the Congress.

Nor can we expect to discover new and cheaper sources of raw materials that could have the effect of lowering our costs of production. That was one of the main sources of new wealth for Americans in the last century. But we know by now what most of the available natural resources are, and we have the technology in place for their extraction.

If we are to create the technological innovation that, in turn, can serve to maintain our competitiveness and standard of living, it must come through new knowledge, new scientific and technological knowledge that can serve as a basis for new products and services.

Over the next ten years, this country will be facing extensive changes. The Nation's demographics will undergo massive adjustments, and the effects on our work force, on our student population, on our military services, and in many other areas will be drastic.

The ability of other nations to produce high technology products and services will continue to grow. If they are not to catch up and surpass us, we must continue to maintain our leadership position in all of those fields of research which have a potential bearing on the development of new technology.

In our hearing today, we want to explore the balance between industrially and Federally funded research. We also want to examine the balance between military-funded research and that part of the Government-funded research which comes from our civil departments and agencies. We are especially interested in the role which our great research universities can and should play in the conduct of basic and applied research in future years.

For us in the Congress, this hearing comes at a particularly important point in time. Congress is now, as you know, in the middle of setting its priorities for the Federal budget. Because it is the first year of the new administration, the budget decisions concerning R&D which are made this year are likely to set the course for several years to come.

We want to welcome our witnesses from Government, industry, and the academic world, who can help us to come to grips with these important issues.

Having said that opening statement, I would ask unanimous consent that the statement of the distinguished ranking member from Pennsylvania, Mr. Walker, be placed in the record at this point. If there is no objection, it is so ordered.

[The prepared statement of Mr. Walker follows:]

HONORABLE ROBERT S. WALKER, (R-PA)
OPENING STATEMENT
HEARING ON CREATING THE NEW WEALTH:
RESEARCH & DEVELOPMENT IN THE 1990S

APRIL 11, 1989

MR. CHAIRMAN, THE OTHER DAY I COULDN'T BELIEVE MY EYES AND EARS. THERE ON THE TV IN FRONT OF ME WERE TIP O'NEILL AND BILL BUCKLEY IN AGREEMENT. I KID YOU NOT, IT WAS COMPLETE AND UNADULTERATED HARMONY. I WAS, NEEDLESS TO SAY, SHOCKED...AND AT FIRST, OF COURSE, MORTIFIED. BUT IN THIS PUBLIC SERVICE ANNOUNCEMENT, TIP AND BILL WERE TOGETHER, TALKING ABOUT THE IMPORTANCE OF SPACE TECHNOLOGY, OF ALL THINGS, TO OUR NATION. THE SIGNIFICANCE OF THIS WAS NOT LOST ON ME. AS PERHAPS ONE OF THE FEW THINGS THOSE TWO HAVE EVER SEEN EYE-TO-EYE ON, IT WAS INDICATIVE OF WHAT MAY BE THE MOST CRUCIAL ISSUE OF THE DAY. IT IS ONE THAT YOU, MR. CHAIRMAN, AND I ALSO STRONGLY AGREE ON. TODAY, CLEARLY, THE BEST ECONOMIC DEVELOPMENT IS TECHNOLOGICAL DEVELOPMENT.

THAT IS WHY WE ARE HERE TODAY -- TO MAKE THE CASE. JUST LAST WEEK WE HEARD THAT THE U.S. UNEMPLOYMENT RATE FELL TO 5%, THE LOWEST LEVEL IN OVER 15 YEARS. MUCH OF THE CREDIT SHOULD GO TO THE FACT THAT THE U.S. HAS OUTSPENT ITS COMPETITORS IN R&D. IN 1987 AMERICA EXPENDED OVER $100 BILLION AS A NATION. THAT'S MORE THAN JAPAN, WEST GERMANY, BRITAIN AND FRANCE COMBINED.

OBVIOUSLY, MONEY IS NOT A PROBLEM. THAT WE LIVE IN A RAPIDLY CHANGING WORLD, WHERE PRODUCT AND PROCESS LIFETIMES ARE SHRINKING ALL THE TIME, IS.

TO MAINTAIN OUR STANDING IN THIS WORLD, WE MUST NOW REDEDICATE OURSELVES AND REDIRECT OUR EFFORTS TO EXPLORING NEW EMERGING TECHNOLOGIES. AT THE SAME TIME, U.S. INDUSTRY WILL HAVE TO APPLY THESE RESEARCH ADVANCES MUCH MORE QUICKLY AND AGGRESSIVELY THAN IN THE PAST. AND THE GOVERNMENT SHOULD HELP BY REMOVING BARRIERS AND BURDENS TO INVESTMENT, REPLACING THEM WITH INCENTIVES FOR RISK-TAKING AND COMMERCIALIZATION. ANTITRUST REFORM TO ALLOW DOMESTIC COMPANIES TO COOPERATE AND POOL RESOURCES ON AN EQUAL FOOTING WITH THEIR WORLD COMPETITION, PERMANENT AND EXPANDED R&D TAX CREDITS, AND A LONG-TERM CAPITAL GAIN RATE CUT CAN ALL BE PROVIDED. NEEDLESS TO SAY, THE BEST CAPITAL COST REDUCTION OF ALL WOULD BE LOW REAL INTEREST RATES THROUGH DEFICIT REDUCTION.

THE RESULT: CUTTING-EDGE INNOVATIONS THAT WILL INCREASE OUR PRODUCTIVITY, MAKING FURTHER AND CONTINUED ECONOMIC GROWTH POSSIBLE. OUT OF SUCH GROWTH COMES OPPORTUNITY IN THE FORM OF WEALTH AND JOBS. AND THESE WILL BE PERMANENT, REAL JOBS BASED FIRMLY IN THE PRIVATE SECTOR, QUITE DIFFERENT FROM SO MANY OF THE SHORT-TERM, MAKE WORK GOVERNMENT PROGRAMS OF THE PAST, AND STILL, UNFORTUNATELY, THE PRESENT.

CONTRAST, FOR INSTANCE, THE MILLIONS OF NEW JOBS CREATED OVER THE LAST SIX YEARS IN THE DEVELOPING AREAS OF COMPUTERS, TELECOMMUNICATIONS, AEROSPACE, AND SERVICES, WITH THE ANEMIC 2,140 CONSTRUCTION JOBS THE COMMERCE DEPARTMENT'S ECONOMIC DEVELOPMENT ADMINISTRATION ESTIMATES IT DIRECTLY CREATED IN 1988. THOSE 2,140 JOBS WERE THE RESULT OF A $120 MILLION TAXPAYER INVESTMENT. THAT'S OVER $55,000 PER JOB AND THEY'RE GONE WHEN THE FEDERAL MONEY IS GONE.

ON THE OTHER HAND, THE POTENTIAL OF MICRO-GRAVITY PRODUCTION, AUTOMATED MANUFACTURING, NEW MATERIALS, FIBER-OPTICS, DIGITAL PROCESSING, SUPERCOMPUTING, HIGH-DEFINITION TELEVISION, SUPERCONDUCTIVITY, AND NOW EVEN FUSION ENERGY HOLDS SUCH UNBELIEVABLY GREATER PROMISE FOR "CREATING THE NEW WEALTH"... AND, NOT TO BE OUTDONE, "BUILDING A BETTER AMERICA."

WE CAN COMPLAIN AND POINT THE FINGER ALL WE WANT ABOUT THE SHORT-TERM, NEAR-SIGHTED MENTALITY OF AMERICAN INDUSTRY, BUT IF WE OURSELVES FOREGO THE NECESSARY INVESTMENT IN OUR FUTURE TO ACCOMMODATE OUR POLITICAL WHIMS, WE IN CONGRESS SHALL BE GUILTY OF THE SAME THING.

THANK YOU, MR. CHAIRMAN.

The CHAIRMAN. I now defer to the distinguished ranking member from Pennsylvania, Mr. Ritter.

Mr. RITTER. Thank you very much, Mr. Chairman.

Right now, with a new administration vitally interested in the role of science and technology in American life, we have the opportunity of a lifetime. We can better fulfill the potential of the $60 billion plus that the Federal Government spends for R&D to improve our international competitiveness.

The title of this hearing, "Creating the New Wealth," is particularly appropriate, for science and technology are at the heart of creating jobs, improving our standard of living, and strengthening that global competitiveness.

There are tough questions we need to try to answer: How can we turn our science and technology faster and more efficiently into products that win global market shares? How can we better set priorities for Federal R&D spending to accommodate the changed nature of global competition in technology-based products? How can we get more private sector market-oriented steering and focus into our Federal R&D economy?

In these next two days, we turn our attention to these questions. The ingredients for dramatic progress in using science and technology to underpin our global competitiveness are there. New attention to the role of science and technology at the highest levels of the administration, from the President's new chief of staff, Dr. Sununu, a former mechanical engineering professor, associate dean, and industry consultant in engineering, and some of his key staffers, to the beginning of a productive debate on R&D priorities, as anyone who was at the SRT subcommittee's hearing on priority setting will attest; and, finally, your leadership, Mr. Chairman, in bringing this distinguished group of experts together to discuss how we will create the new wealth.

These hearings are especially timely as we await a decision on the new science advisor, whom I hope will be a veteran of the global competitive wars in technology-based products and a winner in those wars. That person could help select leadership personnel in the Federal R&D bureaucracy in a top-down manner, choosing players in such a fashion as to have all key players on the same team with the same goals.

I hope that our witnesses from industry, academe, and Government will feel free to put on the table some provocative ideas for the beginning of a system-wide change that can lead to greater optimization of our R&D strength. I am sure that we will hear some interesting proposals from our distinguished witnesses who represent a wide range of knowledge and expertise in science and technology and, in some cases, are friends and colleagues.

With that, I turn back to you, Mr. Chairman, and thank you very much.

The CHAIRMAN. I thank the distinguished gentleman from Pennsylvania.

Are there any other opening statements anyone would like to make?

Mr. SLAUGHTER. Mr. Chairman.

The CHAIRMAN. The gentleman is recognized.

Mr. SLAUGHTER. I would like to say briefly, Mr. Chairman, that I certainly appreciate your initiative in holding these hearings at this time. It is important for the U.S. to be number one in high technology because of the effects upon our national security as well as our economy, and I am very much interested in this subject and congratulate you for bringing it before us.

The CHAIRMAN. I thank the distinguished gentleman.

Does the gentlelady from Rhode Island wish to be heard?

Ms. SCHNEIDER. Yes, thank you, Mr. Chairman.

I would like to add just a few comments in relationship to the testimony that we will hear from one of the witnesses later on.

I would like to focus on one of the themes, mainly the changing composition of the work force of the future, and I think that we need to point out that women will be an increasing part of the work force of the future. From the year 1989 to the year 2000, two out of every three new entrants into the labor force will be women, and when we also recognize that Hispanic women will increase their participation by 85 percent and black women by 33 percent, then certainly the business community had better take a closer look at the kind of directives we are sending.

Another thing that we have to keep in mind is that the majority of the new jobs will require education or training that is beyond high school, but one in eight women workers right now has less than a high school diploma. Last year, the science committee's Task Force on Technology Policy recognized the importance of this issue of adequate science education for women in its report that was approved by the committee, and I hope that we can build further on this record this year.

Thank you, Mr. Chairman.

The CHAIRMAN. I thank the gentlelady.

The chair recognizes the distinguished gentleman from Colorado, Mr. Skaggs.

Mr. SKAGGS. Thank you, Mr. Chairman.

I just want to chime in with my appreciation to the chair for holding these hearings. I do not think they could be more timely or more profound in their implications for our economic and intellectual future, and I look forward to sitting in on as much of it as I can.

Thank you, Mr. Chairman.

The CHAIRMAN. Are there any further opening statements?

[The prepared statement of Mr. Costello follows:]

STATEMENT BY
U.S. REP. JERRY COSTELLO
"CREATING THE NEW WEALTH"
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
APRIL 11, 1989

Mr. Chairman, I represent an area that has been a victim to the industrial decline that has taken place in the last decade. When I was growing up, my district was known for its stockyards and steel, coal and oil refineries. While many of those businesses remain viable, it is clear that others have suffered, at a great cost to our labor force.

One of my priorities in Congress has been to look for ways to restore economic strength to Southwestern Illinois. In addition to trying to rebuild and support these important industries, I realize that there is a new wave of prosperity to be fostered by increasing research and technology investment.

The defense and aviation industries have a strong future in my district. These are two industries that have been traditionally powered by investment in future technologies, and we can see how this investment has resulted in spinoff economic growth - advances in medical technology, transportation and consumer safety.

Today we will discuss the importance of maintaining the strongest possible support for research and development. This has been the priority of other nations, nations that have discovered new goods and new markets and have seen the fruit of

their labor. Research and innovation are the bases for economic possibilities, so I cannot stress enough how important this investment is.

Mr. Chairman, I know how much of a priority new technological research will be for my service in Congress and my congressional district. New industries are facing new challenges, and must be flexible enough to adapt to changes in the marketplace. This is certainly the case in my district, where there is a need for greater innovation to find that new wealth. I look forward to working with businesses, the scientific community and with other members of Congress in an effort to tap this potential which is they key to economic growth.

The CHAIRMAN. The chair recognizes our distinguished first witness, Dr. Brinkman, Executive Director, Research, Physics, AT&T Bell Laboratories, located in the great sovereign State of New Jersey. It is appropriate that we would start this most profound review by Congress of these most important issues with somebody representing the State of New Jersey, of course.

So we want to welcome you and—

Mr. RITTER. Mr. Chairman.

The CHAIRMAN. The gentleman from Pennsylvania.

Mr. RITTER. If the chairman would yield just for a moment—

The CHAIRMAN. Well, remember, New Jersey is next to Pennsylvania.

Mr. RITTER. That is right, and perhaps because it is, we have had the distinct pleasure in Pennsylvania of hosting one of the greatest research laboratories in all of human history, the Bell labs, and I particularly speak of Bell Labs in Allentown, Pennsylvania, and the new Solid State Technology Center in Lower Macungie, and, of course, the AT&T productive capacity that goes with it, not only in my district but throughout the State of Pennsylvania.

Thank you, Mr. Chairman.

The CHAIRMAN. I would like to share a little vignette with the gentleman from Pennsylvania. We in New Jersey took a vote on that before you guys got that project in Allentown.

Dr. Brinkman, you are recognized.

[The biographical sketch of Dr. Brinkman follows:]

WILLIAM F. BRINKMAN
BIOGRAPHY

William F. Brinkman became Executive Director of Physics Research at AT&T Bell Laboratories, Murray Hill, NJ on April 1, 1987. His responsibilities include the direction of research in condensed matter physics, optoelectronic and electronic devices and related areas. Previous to this position, he was Vice President of Research at Sandia National Laboratories in Albuquerque, NM.

He was born in Washington, Missouri, and received his B.S. and Ph.D. (physics) degrees from the University of Missouri in 1960 and 1965, respectively. He joined Bell Laboratories in 1966 after spending one year as an NSF Postdoctoral Fellow at Oxford University (1965). In 1972, he became Head of the Infrared Physics and Electronics Research Department, and in 1974 became the Director of the Chemical Physics Research Laboratory. He held the position of Director of the Physical Research Laboratory from 1981 until moving to Sandia in 1984.

He has worked on theories of condensed matter and his early work also involved the theory of spin fluctuations in metals and other highly correlated Fermi liquids. This work resulted in a new approach to highly correlated liquids in terms of almost localized liquids. The explanation of the superfluid phases of one of the isotopes of helium and many properties of these exotic states of matter was a major contribution in the middle seventies. The theoretical explanation of the existence of electron-hole liquids in semiconductors was another important contribution of Brinkman and his colleagues in this period. Subsequent theoretical work on liquid crystals and incommensurate systems are additional important contributions to the theoretical understanding of condensed matter.

He was a council member of the American Physical Society and is a Fellow in the American Association for the Advancement of Science. He has served on a number of national committees, including chairmanship of the National Academy of Sciences Physics Survey and their Solid-State Sciences Committee. Mr. Brinkman is a member of the National Academy of Sciences.

STATEMENT OF DR. WILLIAM F. BRINKMAN, EXECUTIVE DIRECTOR, RESEARCH, PHYSICS, AT&T BELL LABORATORIES, MURRAY HILL, NEW JERSEY

Dr. BRINKMAN. Well, thank you very much.

The CHAIRMAN. Can you pull your microphone closer.

Dr. BRINKMAN. AT&T certainly enjoys both Pennsylvania and New Jersey as a place to work.

Chairman Roe, members, and staff of the Committee on Science, Space, and Technology, thank you for the opportunity to express my views on the role of research and development in creating new wealth and, in particular, the role American industry must play in creating new wealth. You also asked what the Federal Government's role should be both in supporting R&D and in providing incentives to American industry to bring new wealth to our society.

Wealth is created by leveraging human productivity, and creation of technology is the best leverage. There are a number of steps in the R&D process that creates new technology, and each step is important. Research is divided between basic research, where scientists attempt to understand how nature works, and applied research, which tries to invent new devices and concepts that, at least at the time of conception, are not product specific.

Development can be broken into long-term development, where technological possibilities and/or vision of future markets are the driving forces, and development associated with product realization, where customer needs and market forces are dominant factors. Clearly, with these definitions, development, both short- and long-term, must be done in industry. Industry must also be heavily involved in applied research as it forms the basis for future development.

The United States is unique in that a few large companies have been committed to performance of basic research as well as applied research and development. Except for these few, many research laboratories have been created and have existed for a period, but usually, as the company's profits have decreased, research has been severely cut back and the life has gone out of them. It takes a strong belief in long-term benefits of research to keep this from happening, and this faith only exists in a few places. AT&T has a long history of important products that have originated in its research organization from results of basic research, the most recent being optical fiber and related components that are the basis for the optical communications industry. As a result, its management has had considerable confidence in the value of research.

In Japan, things are quite different. There has historically been no industrial basic research laboratories, although they are beginning to create a few, even some in this country, such as NEC in the great State of New Jersey. Yet, today, R&D as an underpinning of economic strength is widely accepted because the Japanese have shown that high technology can provide a competitive edge in industries such as the electronics and automobile industries. The Japanese industry has, to a large extent, relied on the rest of the world, and primarily the U.S., for basic research and concentrated its efforts on the other phases—applied research, and long- and short-term development—in a successful fashion.

Although the U.S. has done well in basic research, we have struggled to keep up in applied research, and we have not kept up in both long- and short-term development. It is quite clear that one reason for this situation is that private industry in the U.S. does not support R&D at the level necessary to remain competitive. This is evident in surveys of the NSF on the levels of R&D funding spending in the civilian sector and from recent studies performed by the House Committee on Energy and Commerce of the negative effect on R&D of mergers and other acquisitions. Given that this is so, the question is, what can the Federal Government do?

The primary role of the Federal Government must be to create an economic climate favorable to industries that take a longer-term view. Continually cutting back the tax credit for R&D when it should be made permanent, as it was originally conceived, does not indicate that the Government considers R&D a serious issue. Increasing interest rates that decrease our ability to invest for the long term does not help. Allowing enormous fortunes to be made in mergers that contribute little or even negatively to our industrial strength creates a climate where our youth wonder why they would want to work hard in industry when it becomes easier to make money by other means. The Government needs to develop an economic policy that creates a climate favorable to industrial growth and industrial R&D.

Economic policy is not the only issue. American industry needs well trained scientists and engineers, yet we appear to be heading into an era where there will be a shortage. The Federal Government must act to provide support in the science and engineering professions through scholarships and support of university research through which they are trained. Increased emphasis must be placed on manufacturing science and engineering, an area ignored until recently by universities. Attitudinal change toward high technology manufacturing is necessary. Running a factory today is at least as technically challenging as many research jobs.

Trained personnel are not the only reason for supporting university research. Much of the basic research in this country and a good fraction of the applied research is performed at universities. We cannot sit on our laurels in basic research. Therefore, I heartily support the proposed increases in the budgets of the NSF, but we should keep in mind that the NSF's primary role should be support basic research. For this reason, I do not believe one should expect increases in its budget to have a major impact on the short-term issues of competitiveness or economic health. These issues are primarily industrial issues to be solved by industry with Government support.

To help in this arena, strong emphasis needs to be placed on applied research and long-term development that address critical technologies such as integrated circuits, high-definition television, optical communications, and light-weight high-strength materials, to name a few. Consortia, such as Sematech, are a help. The high-definition television initiative is also good, but more needs to be done. At the moment, these activities are primarily in the DOD. It may be that an agency whose mission is to support long-term R&D, as related to industrial economic health, will be needed in the

future, but I think we should learn how well consortia work before we do that.

The Federal Government must also create a climate in which technological change can occur. For example, this country must address the regulatory and standards issues behind high-definition television as well as the technical issues in an efficient and timely way so that we can regain leadership in this important industry.

In telecommunications, we can see the emergence of optical fiber communications to the home which will make possible dial-up TV, high-speed data communications, and eventually ubiquitous picture-phones. We not only want to motivate scientists and engineers to create the technology to make these innovations possible, we must create a means of putting them in place.

In conclusion, the Federal Government has a broad ranging role in helping to create the new wealth, and that role must be based upon leadership with a vision of what the future can be and upon the actions that make it possible.

Thank you.

[The prepared statement of Dr. Brinkman follows:]

Statement of

W. F. Brinkman
Executive Director, Research, Physics
AT&T Bell Laboratories

before the
Committee on Science, Space and Technology

April 11, 1989

Chairman Roe, members and staff of the Committee on Science, Space and Technology - thank you for the opportunity to express my views on the role of Research and Development in creating new wealth and, in particular, the role American industry must play in creating new wealth. You also asked what the Federal government's role should be, both in supporting R&D and in providing incentives to American industry to bring new wealth to our society.

Wealth is created by leveraging human productivity and creation of technology is the best leverage. There are a number of steps in the R&D process that creates new technology and each step is important. Research is divided between basic research where scientists attempt to understand how nature works, and applied research which tries to invent new devices and concepts that at least at the time of conception is not product specific. Development can be broken into long-term development where technological possibilities and/or a vision of future markets are the driving forces and, development associated with product realization where customer needs and market forces are dominant factors. Clearly with these definitions, development both short and long term must be done in industry. Industry must also be heavily involved in applied research as it forms the basis for future development.

The United States is unique in that a few large companies have been committed to performance of basic research as well as applied research and

development. Except for these few, many research laboratories have been created and have existed for a period, but usually as the company's profits have decreased research has been severely cut back and the life has gone out of them. It takes a strong belief in the long-term benefits of research to keep this from happening, and this faith only exists in a few places. AT&T has a long history of important products that have originated in its research organization from results of basic research - the most recent being optical fiber and related components that are the basis for the optical communications industry. As a result, its management has had considerable confidence in the value of research.

In Japan, there has historically been no industrial basic research laboratories, although they are beginning to create a few - even some of them in this country, such as the NEC Laboratory in Princeton, New Jersey. Yet today, R&D as an underpinning of economic strength is widely accepted because the Japanese have shown that high technology can provide a competitive edge in industries such as the electronics and automobile industries. Japanese industry has, to a large extent, relied on the rest of the world and primarily the U.S. for basic research and has concentrated its efforts on the other phases - applied research, and long- and short-term development, in a highly successful fashion.

Although the U.S. has done well in basic research, we have struggled to keep up in applied research and we have not kept up in both long- and short-term development. It is quite clear that one reason for this situation is

that private industry in the U.S. does not support R&D at the level necessary to remain competitive. This is evident from surveys of the NSF on the levels of R&D spending in the civilian sector and from recent studies performed for the House Committee on Energy and Commerce of the negative effect on R&D of mergers and other acquisitions. Given that this is so, the question is - What can the Federal government do?

The primary role of the Federal government must be to create an economic climate favorable to industries that take a longer-term view. Continually cutting back the tax credit for R&D when it should be made permanent, as it was originally conceived, does not indicate that the government considers R&D a serious issue. Increasing interest rates that decrease our ability to invest for the long term doesn't help. Allowing enormous fortunes to be made in mergers that contribute little, or even negatively to our industrial strength, creates a climate where our youth wonder why they would want to work hard in industry when it is so much easier to make money by other means. The government needs to develop an economic policy that creates a climate favorable to industrial growth and industrial R&D.

Economic policy is not the only issue. American industry needs well-trained scientists and engineers, yet we appear to be heading into an era in which there will be a shortage. The Federal government must act to provide support in the science and engineering professions through scholarships and

support of university research through which they are trained. Increased emphasis must be placed on manufacturing science and engineering, an area ignored until recently by universities. Attitudinal change toward high technology manufacturing is necessary. Running a factory today is at least as technically challenging as many research jobs.

Trained personnel are not the only reason for supporting university research. Much of the basic research in this country and a good fraction of the applied research is performed at universities. We cannot sit on our laurels in basic research. Therefore, I heartily support the proposed increases in the budgets of the NSF. But we should keep in mind that the NSF's primary role must be to support basic research. For this reason, I do not think one should expect increases in its budget to have a major impact on the short-term issues of competitiveness on economic health. These issues are primarily industrial issues to be solved by industry with government support.

To help in this arena, strong emphasis needs to be placed on applied research and long-term development that addresses critical technologies, such as integrated circuits, high definition television, optical communications, light weight-high strength materials to name a few. Consortia, such as SEMATECH, are a help. The HDTV initiative is also good, but more needs to be done. At the moment these activities are primarily in the DOD. It may be that an agency

whose mission is to support long-term R&D, as related to industrial economic health, will be needed in the future but we should learn how well consortia work first.

The Federal government must also create a climate in which technological change can occur. For example, this country must address the regulatory and standards issues behind high definition television, as well as the technical issues, in an efficient and timely way so that we can regain leadership of this important industry. In telecommunications, one can see the emergence of optical fiber communications to the home which will make possible dial-up TV, high-speed data communications, and eventually ubiquous picturephones. We not only want to motivate scientists and engineers to create the technology to make these innovations possible, but we must also create the means for putting them in place.

In conclusion, the Federal government has a broad-reaching role in helping to create the new wealth, and that role must be based upon leadership with a vision of what the future can be and upon actions that make it possible.

The CHAIRMAN. Thank you for your splendid testimony.

For questions, the chair recognizes the gentlelady from Rhode Island.

Ms. SCHNEIDER. Thank you, Mr. Chairman.

I would like to begin with some broad questions. Obviously, there are a series of different moves that we could make as Members of Congress and you as a leader of the business community. But as you review the various challenges in order to help make us more competitive, you look at some of the antitrust reform that is frequently discussed, the R&D tax credits which you mentioned, the capital gains cuts, the cost of capital as it relates to our deficit, and also low interest rates, of those various concerns, what is foremost on your mind?

Dr. BRINKMAN. I think at the moment the two things that are foremost on my mind are the cost of capital and the R&D credit. I think that Congress has managed to nibble away at the R&D credit in a rather interesting way over the years and eventually brought it down to where it is minimal, and it seems to me that is just a negative sign. I do not believe Congress should want to position itself in that fashion relative to this issue.

The second thing, I think, is the major impact on industrial research, is really the cost of capital these days, and that is one of the biggest things.

The antitrust question is a much more complex issue which—I am really not an economist so I am not a total expert on it, but it seems to me that right now there are plenty of companies in this country that have a lot of freedom to do what they need to do, and I do not find myself inhibited by antitrust laws at the moment.

The CHAIRMAN. You say you do or you do not?

Dr. BRINKMAN. Do not.

The CHAIRMAN. Okay.

Ms. SCHNEIDER. Well, on the R&D tax credit, I think that there is just about unanimous support on this committee, and certainly coming from our President also, he has clearly indicated, too, his desires to extend the R&D tax credit. So I can not help but think that your wish number one will be taken care of.

I think a far more difficult challenge that we are facing is the cost of capital and the understanding on the part of Members of Congress as to how it relates to individual savings and how it also relates to our own Government's savings in terms of reducing our deficit. One of the most frustrating things to me is that so often we hear from witnesses encouraging us to increase the science budget, but rarely do we hear any articulation of our concern about the imbalance of the science budget, whereas more than half of it—close to 73 percent—is being used for defense, and that has eroded the commercial part of our research budget.

Dr. BRINKMAN. I think it is very obvious when you look at the Japanese—I mean the Japanese industry spends very little federal money on research and R&D, and it almost all comes from the private sector, and we do not balance that very well at all. And I think rather than trying to figure out how to spend your money I would rather see to it that we can have some money that we would spend, and that takes an attitudinal change in this country.

The CHAIRMAN. Would the gentlelady yield for a minute?

Ms. SCHNEIDER. Yes, I would be happy to yield.

The CHAIRMAN. On that question, you made the point that the Japanese have not been using a substantive amount of their federal funds for that purpose, but then you also made the point in your testimony that the Japanese were not really doing that much in industry from the research point of view. And then, thirdly, that a goodly portion of their background research data was coming from the United States and elsewhere. Why do not you clarify that for us.

Dr. BRINKMAN. Yes. What I said was that Japanese industry does not do what I define to be basic research, really asking questions about nature and that sort of thing. They start very much at the applied level. For example, I could give you an example. You hear a lot about neural networks in the news in this country, and that came out of basic research in neurobiology and it's physics, and the Japanese companies really would not do that kind of research in their companies. They will pick it up as a tool for programming tools and things like that as a technology, but they will pick it up at a later stage, okay, than we would. So you see that very much across the board.

Now the Japanese are trying to change. They are trying to move into basic research in a major move in Japan. So they are trying to correct this deficiency which they see as a deficiency in their country.

We have tended to put a tremendous emphasis on basic research in this country and ignore particularly long-term development, which I think is one of the things they do exceedingly well. They stick with technologies much longer than we do, and continue to develop them, and continue to try them out in various markets until they finally find the right market niche. We have got to learn to do that better.

It is that difference. It is a very big, important difference that you see. I mean, for instance, we are very shortly going to have an exchange with NTT, and even we at Bell Laboratories find ourselves doing more basic research than NTT does, so when we have these exchanges, which are supposed to be at the research level, we find that we are on the more researchy side than NTT is, and NTT, of course, is still a nice big entity like we used to be.

The CHAIRMAN. The gentlelady is recognized.

Ms. SCHNEIDER. Thank you.

To follow up on your one point there, do you feel that public disclosure of some of the technical findings and some of our advances then should be held a little closer to the chest if the Japanese are then picking up where we leave off?

Dr. BRINKMAN. Well, now you are talking about a very different issue.

Ms. SCHNEIDER. I realize that.

Dr. BRINKMAN. You have twisted that one around.

I have always been a big believer that basic research should be common knowledge, and the reason for that is not that I am trying to give something away, it is that I think I get more back for it having made it common knowledge than I would if I held it.

The point is that what happens is, if you put a new discovery out on to the street in the science community, so to speak, what hap-

pens is, everybody picks it up and chews on it and takes it apart and finds new aspects of it, and enormous world-wide effort gets created, and progress is made. You can see that, for instance, today if you look at what is happening with the so-called cold fusion. Everybody in the world is looking at cold fusion to figure out whether it is true or not, and we will learn a lot more about that a lot faster by being open than we would if we held it.

Now when do you not be open? The answer is that as you move toward the development process where you are starting to talk about leverage advantages in the marketplace, then you cannot be open any longer and you have to hold things close. So there is a fine line there that has to be determined and has to be drawn, and you have to learn where it is and draw it. But you do not want to draw it all the way back into the basic research side.

Ms. SCHNEIDER. Let me ask one last quick question. When you look at the Federal R&D dollar, do you realize that the commercial investments are being used—or I should say the other way around perhaps—that the defense dollar is being used at the expense of the commercial dollar investment?

Dr. BRINKMAN. Let us see. I guess I do not exactly understand what you mean by "being used at the expense of" in the sense that there is more defense dollar than there is anything else.

Ms. SCHNEIDER. Right. And when we are working with a limited pie, we have to determine where to set our priorities in the commercial sector.

Dr. BRINKMAN. That is right.

Ms. SCHNEIDER. And we have the business community coming to us and saying, "We need to spend all of this money on science research," and, at the same time, you want your cake and eat it too, and I am suggesting that we are in a position where we have to make some hard choices.

Dr. BRINKMAN. Oh, yes.

Ms. SCHNEIDER. So where do we make those cuts? In the research for AIDS, or do we take the money away from, you know, acid rain, or what? Or do we take it from defense?

Dr. BRINKMAN. Well, look. My belief is that you are going to have to take it from somewhere. People point to defense today as the easy one because it is so big. The thing I believe, however, is that rather than explicit Federal funding I think you have to figure out ways to encourage and enhance private spending in the R&D process.

Particularly in development, it really is a private industry issue, and you want to stimulate that, and I am not sure that just throwing money at it is the solution from Washington.

Ms. SCHNEIDER. Well, as you pointed out, the development in R&D on the part of business, though, is pretty significant compared to the Japanese. So, you know, that is a step in the right direction.

But when you talk about change of attitude, I think that the business community has to acknowledge the fact that we have had a sacred cow for some time now, and there has to be some courage coming from the business community to say, "Look, we are investing here in research in defense; we are seeing the offshoots from the defense sector into the commercial sector reduced since we have passed that electronics era." And now we are seeing the re-

verse; more developments are coming from the commercial sector into defense, and suddenly we should acknowledge the fact that the business community will stand strong and say, "We support you Members of Congress; we would like to see some shifts taking place," because unless we hear it from you, let me say that our title is Representative; we are not going to jump out on a limb unless we know that the grass roots, you know, your roots, are there in support of us.

Dr. BRINKMAN. I certainly believe that we have to shift our emphasis toward the civilian sector. I believe that if you look at the world today, the military threats are considerably less than they have ever been in a long time to this country, and what is really a major threat is economic health, and if we do not respond to that in every way we possibly understand how to do, I think we are missing the boat.

Now I consider myself to be right in the middle of that fight. You know, one of my arguments about keeping people in American industry rather than going off to university is that, gee, why would you want to go off to university? because the big fight is right here, and life is going to be more interesting here than it is anywhere, and I believe that. So we definitely have to change our attitude in that sense.

Ms. SCHNEIDER. Great.

Thank you, Mr. Chairman. Thank you, Dr. Brinkman.

The CHAIRMAN. Any further questions on my right here?

The gentleman from Pennsylvania, Mr. Walgren.

Mr. WALGREN. Thank you, Mr. Chairman.

You mention that we should go a little slow on the critical technology support from the Federal focus.

Dr. BRINKMAN. Let's see. I did not say go slow; what I said is, I am not totally convinced that we should create a second, separate civilian agency at this time.

Mr. WALGREN. I see. Okay.

Until we learn how well consortia work first, what can you tell us about how consortia are doing, and what are the initial signs?

Dr. BRINKMAN. A lot of them have been formed, and my first impression of Sematech is that it is going to have a major impact. I think it is causing industry to work together in a way which they haven't worked in any prior time. It is working at a level in development, early development, long-term development stage, which is new and different for American industry. So I am optimistic about that particular consortium.

I do not know about others. There are a lot of consortia starting up in superconductivity, for instance, today, and I am not sure what the outcome of those is going to be. And the other thing I would say is that I think we want to be very careful and not be too much misled about consortia.

While I am all in favor of those things, I think the competitive issue is product realization. American industry has to get better and quicker in turning around a development process into a product, and I do not believe that that is going to be the result of consortia, if you know the truth. I believe that industries, companies themselves, have got to do that, and that is our job, we have got to work at that very hard. I sometimes get a little worried that con-

sortia will dilute our effort rather than enhance our effort, because the real competitive issue is products today, and high technology products, and learning how to coordinate marketing sales, development, all those aspects of making products, and I do not think we should kid ourselves. That is what American industry has got to do, and we have got to learn how to do that much more efficiently than we do it today.

Mr. WALGREN. You said that the Japanese seem to stick with the development process longer than we do and work it around until it finally realizes a product, where American industry tends to pull back earlier and not follow it through. Why is that?

Dr. BRINKMAN. Well, I think it is support.

Mr. WALGREN. Are there incentives in the tax code to do that?

Dr. BRINKMAN. There are no incentives in the tax code that does that, but I think the fact that you have a much larger R&D bill than Japan—

Mr. WALGREN. What about the immediacy of write-offs that might be helpful to realize losses, or swallow them in the balance sheet, or whatever they do? I am always reading that some company took a write-off of x number of thousands of dollars in losses. Might that be an incentive that is presently in the tax code? If it were not there, they would have to stick with it and see if they could not make a product out of their investment?

Dr. BRINKMAN. That is interesting. I do not know. I would have to think about that. I am sorry, I have not thought about write-offs in that sense.

The CHAIRMAN. Will the gentleman yield?

Mr. WALGREN. I would be happy to yield.

The CHAIRMAN. I think that Mr. Walgren is striking at a very important point.

First of all, the purpose of the hearings is not only—we are not going back into just the competitiveness issue. What we are really talking about is that science-based technology and education is the fountainhead to create the new wealth, and if the Government or industry, by tax methods or whatever, curtails that effort or materially reduces that, that is going to hurt us very, very badly looking to the future. There is not enough there in the present resources to do that.

But you make a very important point, which I do not think has been touched upon in too many hearings around here, on the buy-out issue, because I look at that buy-out issue to be an extremely important movement taking place as it relates to the dissipation of capital, because, in effect, they are transferring the capital, you know, from pension funds and everything else into cash, into other purposes, not going back to R&D, and when you dissipate the capital of large corporations you are materially hurting their longer-range growth; I would think so.

Dr. BRINKMAN. Well, that certainly is true. You know, we probably can give you examples on where the lack of capital has essentially driven American industry out of business. I always think of the liquid crystal display, the thing that is in your watch. You know, we are out of that business; America is not in that business effectively any more today; the Japanese have it all.

What happened was, that was an American invention, and instantaneously, as usual with us, a bunch of venture companies sprung up around it and made the first watches and made the first displays, and then, as it became the second and third generation of technology, it required bigger and bigger investments and more automation and high volume production, and these small companies just could not hack it with the amount of capital needed to do that, and eventually Hitachi took over the whole business, and so you can see those kinds of things happening.

The CHAIRMAN. Yes, but, if the gentleman would yield one more minute; I did not mean to take his time; I will give him plenty of time. The issue that we should be allowing these enormous mergers and buy-outs to take place is a much greater problem, I believe, than people realize in this country. I think we talk about the free enterprise system, that they want to do their thing and they are not breaking any rule. That does not happen in England or in Germany; they have got to get permission of their governments to be able to do that, as you know. But that is dissipating the very capital that would be utilized in the research and advanced productivity areas. Is that a reasonable point to make?

Dr. BRINKMAN. I think you are right.

The CHAIRMAN. Okay.

The gentleman is recognized.

Mr. WALGREN. If the gentleman would continue on the same point, in my area, in Pittsburgh, Gulf Oil was acquired by Chevron in a friendly takeover, and yet Chevron was located on the west coast and Gulf Oil was in Pittsburgh. Gulf Oil had a totally intact research laboratory that was the state of the art for a major United States oil company, involving the most sophisticated equipment, a tremendously large physical plant, and Chevron also had a research laboratory, so they simply walked away from the research laboratory in Pittsburgh, Pennsylvania.

Now it was turned over essentially as a charitable gift to the university, and the university has been trying to breathe some life into this, but it is very hard, it is very expensive to carry, and it may be that good things will come out of that because there is a whole new cadre of people trying to make something happen there.

On the other hand, the research projects that were justified in a major United States oil company were simply terminated and dropped, and so that whole research effort essentially just plain stopped, and this is the result of the buy-outs that the chairman raises.

Dr. BRINKMAN. Congressman Roe surely knows about one in New Jersey of a similar nature.

The CHAIRMAN. Interestingly enough, if the gentleman would yield, on the buy-out of the Singer thing, well, now there is a German firm going to buy out Plessey from England. You know, here we are not just talking about buy-outs alone, we are talking about all that technology being transferred—that was the point you were making—being transferred all over simply through the process of buying out.

Dr. BRINKMAN. Right.

The CHAIRMAN. How much do I buy out? How much are my patents protected? How much is my technical know-how protected in that kind of a buy-out when it is international in nature?

The gentleman is recognized.

Mr. WALGREN. Only in conclusion, Mr. Chairman, I could not help but be struck by your statement that we do not stick with it long enough, and there may be points in our system that are sort of larger economic points that we ought to be thinking about anyway.

You have in your statement that research laboratories that companies have developed oftentimes die with the company, and when the company goes into decline the life goes out of the research laboratory.

Dr. BRINKMAN. The company does not necessarily die, but it just goes through a bad period, so then the research laboratory dies because they have cut it so badly that all their good people leave, and then it is very hard to recover them because nobody wants to go to work there.

Mr. WALGREN. But I am not enough of an economist to know quite what the Japanese situation is, but my instinct is that they have been able to maintain the strength of their companies' support for research, so they are operating quite on a level, an increasing plain, and ours is going up and down and ending.

Thank you, Mr. Chairman.

The CHAIRMAN. Any further questions?

Mr. Rohrabacher, the gentleman from California, is recognized.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

If I might ask, would this be a proper summary, that the Japanese tend to have a greater commitment to apply their technology, to actually use it?

Dr. BRINKMAN. Oh, yes.

Mr. ROHRABACHER. Well, then, you would see that this—and again, would not that lead you to the conclusion that what we have in terms of creating this new wealth that we are looking for, the problem lies in our business rather than in our Government, our business structure and the people who run our major corporations and their willingness to apply technology, to take the chances, to be the entrepreneurs that they are supposed to be?

Dr. BRINKMAN. Yes, I think I essentially said that to some extent, and the whole point is that, somehow or another, this country has a climate in which R&D and industrial manufacturing and things like that are not considered to be as important as they are in Japan.

Mr. ROHRABACHER. Well, it is not just R&D, but it is actually applying the technology. After the research and development have done their job, our business is not taking advantage of some of the opportunities that technology has made available to us. Is that right?

Dr. BRINKMAN. that is right.

Mr. ROHRABACHER. Well, with that in mind—

Dr. BRINKMAN. We came out of an era in which we had people like Nesbitt going around and saying this country was going to be a service country, that we were not going to even do any manufac-

turing, and we are now beginning to recognize that, hey, maybe we can't afford to go that route.

Mr. ROHRABACHER. Well, with that in mind, would not you say that some of the—and with all due respect to my chairman, would not you say that that would lead you to the conclusion that some of these major corporations, some of the leadership of these corporations, deserve to be bought out and deserve to be kicked out on their butts because they are not really applying the technology that is available? Maybe they have got too complacent. Maybe their stock is lower in price than it should be because the management itself is not doing a good job and you have got somebody who is coming along and willing to take over the company. Maybe these big companies deserve to have new management.

Dr. BRINKMAN. I think those possibilities exist as well as other possibilities, but I would not have thought that the way mergers are going in this country it is based on that kind of criteria.

Mr. ROHRABACHER. But there is a lot of buy-outs that are taking place. There's a lot of buy-outs that are taking place, there's a lot of people who are coming over in these corporate takeovers, they are taking over from people who have become complacent, and that is a market function, is it not? Does not the free market take companies that are being run by people who are not utilizing the full potential of their company and replace them with more aggressive people who are coming in to make a profit with what potential a company has?

Dr. BRINKMAN. Well, I would like to think that that was what was really going on, and I would feel very good if it were, but I doubt it.

Mr. ROHRABACHER. Well, let me ask you about another comment that you made in passing. Is not the money that we spend in technology that we use to preserve the peace of this country a great investment? Isn't the fact that we have had 40 years of peace worth the amount of money that we have put into military technology?

Dr. BRINKMAN. I think that there is no question about military technology having given us a prolonged period of peace, although not 40 years, since we have a few wars in between there, but I believe if you ask what the priorities are today you come up with a slightly different answer than what we have currently—the way we are currently funding things.

Mr. ROHRABACHER. Excuse me, I did not hear.

Dr. BRINKMAN. I said if you asked about priorities today, not 40 years ago, then I think you come up with a slightly different answer.

Mr. ROHRABACHER. Some of this money that is going into military technology—and, again, I absolutely agree with the assumption that we can drain our private sector from resources and put it into the military, and I am not in favor of doing that.

But do not we have a lot of spill-overs? For example, wasn't the 707, for example, a military tanker plane that turned into a work horse for private industry?

Dr. BRINKMAN. It is certainly true that there has been spin-off from the military; I think that no one would argue about that.

Mr. ROHRABACHER. Right. For example, the national aerospace plane right now has been developed to some degree on Department of Defense research and development, is it not?

Dr. BRINKMAN. Yes.

Mr. ROHRABACHER. Doesn't that really hold a lot of hope for us in the future, and is not this a good investment?

Dr. BRINKMAN. I do not know yet; I am not convinced at all.

Mr. ROHRABACHER. Thank you very much. That is all I have.

The CHAIRMAN. The chair recognizes the distinguished gentleman from Colorado, Mr. Skaggs.

Mr. SKAGGS. Thank you, Mr. Chairman.

Dr. Brinkman, I am interested if you could help us deal with public policy issues we are going to be facing for several years now in this area, which, at least at some common point, involve: What is Government's role? What should the Government identify as its responsibility in helping the private sector? and I guess it would be helpful if you are able to offer some kind of theoretical or analytical construct for us as public policy makers to try to apply what questions, what tests, should we be applying in areas of emerging technology to determine what we should be doing to either dive in or stay on the shore as public policy makers. The high-definition television issue was the subject of hearings recently before this committee.

On the one hand, there seemed to be a school of thought that this is right for very direct Federal Government intervention and coalition building. On the other hand, I visited with some of the people in the industry in my part of the country who said, "No; what we need here is just the Government to set the standards and the ground rules; there's plenty of profitability here that will attract the requisite private investment to make it happen."

It would be very helpful to me, I think, and to all of us, if we could have some of those generic questions that we ought to be asking.

Dr. BRINKMAN. Well, I do not know if I can quite fill that bill or not, but it seems to me that what I tried to say earlier is that the first order of the Federal Government's role is to set the environment and the regulation, the economic strategy, that encourages private industry to do their job well.

Now something like high-definition television, it seems to me, that is a situation in which the Federal Government can take one step further, because effectively the U.S. industry is almost out of the TV business today, and so in that case you are trying to stimulate back into existence to a large extent an industry that we really completely botched up, to tell the truth, so you take more drastic measures. And so it seems to me the important thing, as far as actual funding of things of that type, is making a judgment of where American industry is failing, and where it needs special help. And I think you have sort of done that, at least in a couple of cases. Sematech and high-definition TV, I think, are good examples of that kind of thing. But I do not think you want to do that across the board.

It seems to me that one of the strategies that the Japanese Government has done well is to be very selective. They do not put a lot of money into these various consortia and national initiatives by

MITI and that sort of thing, but they choose very well the areas that they emphasize. By doing so, they make them national issues, and I think that is the kind of thing you have to do, is try to come up with ways of picking those things that American industry needs to be beat on a bit and be told that they ought to get their act together on, and emphasize those. Otherwise, it is a matter of nurturing the industry by the proper economic climate, the proper education of people to go into it, and those kinds of things.

Mr. SKAGGS. I infer that you would not be able to point to any objective criteria that at a certain level of risk or scale of enterprise we get beyond the capabilities of the private sector acting on its own and there is, in some sense, an identifiable point at which the Federal Government may have a catalytic role to play.

Dr. BRINKMAN. I think there is a role of that type to play in international markets where other Federal Government—other governments support their industries when they go out and compete in the international market, but I do not see a level in R&D where all of a sudden it says, "Gee, the government has to do it."

Maybe the aerospace plane is an example of something that has to become a national initiative. I mean the reason that has to be a national initiative, in my opinion, it is so far out in the future and so big that no one industry can handle it, and so that is an example of one that is over the threshold that you are looking for.

Most things that are more near-term than that, that have a real product at the end, I think the Federal Government does not need to be involved.

Mr. SKAGGS. I am sorry, I could not hear the last part of your—

Dr. BRINKMAN. Most near-term things, near-term product things, I think it is not helpful to have the Federal Government involved, except in situations where industries do not exist.

Mr. SKAGGS. Thank you, Mr. Chairman.

The CHAIRMAN. I thank the gentleman.

The chair recognizes the distinguished gentleman from Connecticut, Mr. Shays.

Mr. SHAYS. Thank you, Mr. Chairman.

I am not a pessimistic person by nature, but, very honestly, when I think about what you are saying and some of the questions that were asked by our chairman, it is hard not to be a little pessimistic, because your message to me is that, let it be done in the private sector rather than the public sector, it is preferable. But when I look at the public sector what I am having—and I come from an area with the third largest concentration of corporate headquarters in the country, Fairfield County, where Singer was bought out, and so on.

The message I am getting from the CEO's is that the people who own these businesses are money managers, and they think in the short run, and that any company that is well run is going to, in essence, be worth less in its parts—excuse me—its parts are going to be worth more than the whole if they, in fact, are thinking in the long run, that if they are thinking in the long run, they are going to have an undervalued stock, and then they are going to be prime targets for buy-outs.

that is not true in every instance, because clearly you are going to want to buy out certain—certain companies are going to be run

inefficiently, and you are going to want to buy them out. But take the situation of, say, Champion. Its parts are worth far more than its whole, and if they want to invest in a billion-dollar plant, their stock will go down rather than up, but in the long run it will have tremendous benefit to the company and the stockholders.

So I guess my point to you would be to ask you how we can have faith in the ability of our companies. By definition, research is long-term; correct?

Dr. BRINKMAN. True.

Mr. SHAYS. And, by definition, if it is long-term, does not that undervalue the stock of the companies?

Dr. BRINKMAN. Well, I think you are just phrasing in a different way the thing that I think we have to address, and that is that the economic environment of this country is not tuned in such a way that American industry wants to do the long-term development—research and development that is necessary to keep us economically healthy.

What I am suggesting is that the most important thing to do is to think about ways to change that. I am not an economist, and so I do not have a great deal of expertise on how to do that, but I think that is the central issue, and I do not think you can change that by supporting R&D at the Federal level, I think you have to change the economic scene in this country to change that.

Mr. SHAYS. But I do not know how we can do it, even giving tax write-offs and so on to companies that do research, if, in the end, they still have to weigh the thought that they undervalue their stock in the process.

Dr. BRINKMAN. You know, it depends how things are written off, it depends what kind of tax credit you get on write-offs; a whole bunch of things can change that picture.

The CHAIRMAN. Will the gentleman yield?

Mr. SHAYS. Sure.

The CHAIRMAN. I think the gentleman—I am glad he is bringing it up—is making a very, very important point, and I hear what you are saying, but this is a new phenomenon. I mean the whole idea of junk bonds and so forth and so on is new, and it seems to me, not that I believe there should be 10 million regulations—God, there is enough of them—but if people can just go on the point you made in your own testimony, if they can go and sell out and make $500 million because of the sum of the parts, as the gentleman from Connecticut is talking about, why should I worry about, what am I doing on the bottom line anyway? The purpose for being in business is not to be altruistic, at least not in this country.

But it seems to me that when we got into the difficulty years ago—I guess it was during the Roosevelt time, not that I remember it, I was very young at that point—but the idea of the antitrust issue, there was a reason to do an antitrust bill at that point. I am not so sure in this cycle we are in now from a business environmental point of view, and, in fact, I am sure that the antitrust laws have to be modernized or modified, in my personal judgment, particularly where research is involved.

But is not the same phenomenon of this drainage of enormous amounts of capital—four, five, six, seven hundred million dollars, a billion/two dollars, being drained out of that economy, being

drained out of that company is certainly not enhancing the capital—what would you say?—capital formation or the use of capital for research.

Dr. BRINKMAN. I agree.

The CHAIRMAN. Okay.

I thank the gentleman for yielding.

Mr. SHAYS. Thank you.

Just one last question. With all due respect to those who ask the question, but is not it almost a little irrelevant to ask whether there are some trade-offs from military to the public sector because—let me put it this way; let me ask it differently. Isn't the spin-off from military research to the private sector small? In other words, is not it a very inefficient way to bring benefits to the public sector?

Dr. BRINKMAN. Yes. Spin-off from the military is big or small, depending on the eyes of the beholder, and, I mean, if you go, you can get hundreds of examples cited of important spin-offs from the military, and I think that that has been true. I do not see any reason why anyone would want to deny that.

What worries me most about R&D and things like that associated with military spending is that the net result of that R&D is quite different than what the net result is in the consumer side. Things have to be more economical, things have to be done in volume—in different size volumes, and things like that. So there is a very big cultural difference that occurs when you are doing R&D and development and manufacture for the military versus the commercial sector, and those cultural differences, I think, have an impact on this country.

I mean no one can deny that our—I mean our airplane industry is successful partly because of all the R&D that military put into it, and I would not want to deny that, and I do not think we should. But I do think these cultural differences are something we have, you know, a slightly gold-plated mentality because of it.

Mr. SHAYS. Just a last question. I have someone in my district who has become phenomenally wealthy and some very simple economic ideas, and he has basically—he basically says that any time interest rates are over 8 percent you are not going to see capital formation, you are not going to see investment, you are not going to see research, and that he loves to go back over time and show how that historically has been true. Do you think there is any basis for that?

Dr. BRINKMAN. Well, I thought I said that earlier.

Mr. SHAYS. You may have. I am sorry. I was not here in the beginning.

Dr. BRINKMAN. That, in fact, I think high interest rates are very negative toward R&D.

Mr. SHAYS. Thank you.

The CHAIRMAN. Are there any further questions?

We want to thank you, Dr. Brinkman, very much. I know you have to get a plane. We thank you for being with us, and we will be talking with you again further, I am sure. Thank you very much.

Our next witness for this morning is Dr. Arnold H. Packer, co-author of "Workforce 2000," Hudson Institute, Indianapolis, Indiana.

We want to welcome you, Doctor, and if you would go right ahead.

[The biographical sketch of Dr. Packer follows:]

Dr. Arnold Packer is a Senior Research Fellow at Hudson Institute and Deputy Director of the Work Force 2000 study. A former professional engineer, Dr. Packer came to Washington in 1969 as an economist for the Office of Management and Budget with responsibility for forecasting the U.S. economy. After working on energy policy for the Committee for Economic Development, he became the first chief economist for the newly-formed executive branch to become Assistant Secretary for Policy, Evaluation, and Research at the U.S. Department of Labor. In 1982, he formed Interactive Training, Inc., to produce interactive vidodisc training courses (SKILLPACS) to teach basic workplace skills.

Dr. Packer has written widely about economics, employment and training policies, and the use of technology for training, including a book published by the MIT press, on computer-based models of the economy. He holds a PhD. in economics from the University of North Carolina at Chapel Hill. He also has a masters degree in business administration (from Sacramento State) and a bachelors degree in mechanical engineering (from the Brooklyn Polytechnic University).

STATEMENT OF DR. ARNOLD H. PACKER, SENIOR RESEARCH FELLOW, HUDSON INSTITUTE, INDIANAPOLIS, INDIANA

Dr. PACKER. Thank you, Mr. Chairman. It is a pleasure to be here today and an honor for a mere economist to be among so many eminent hard scientists.

The CHAIRMAN. Now, you see, you made a mistake there. You are listed as the demographic person. When you said "economist," now you are going to get nine million questions.

Welcome.

Dr. PACKER. Given how many questions there are, I will paraphrase my statement and hope it can be put in the record in full.

The CHAIRMAN. We have no objection. Your statement will be put in full in the record. It is a good statement, so I hope you give us the advantage of your observations.

Dr. PACKER. You mentioned the book my colleague, Bill Johnston, and I wrote, "Workforce 2000." I would like to submit the executive summary for the record also.

[The summary follows Dr. Packer's prepared statement:]

Dr. PACKER. We made some recommendations, which I think boil down to two. One is that we need to increase productivity in the service sector, and especially in Government-financed services such as education and health, and I think that is one of the criteria you might use for looking at R&D. When the Government has a major responsibility, it has a major responsibility for the R&D. Defense is an excellent example. And, secondly, we need to educate and train a diverse population for the work place of the future, and I think those are the two primary recommendations.

Why do we need to increase service sector productivity? Because overall productivity over the last 15 years, since 1973, has been abysmal, whether we compare it to the Japanese, to our own past history, or, most important, to our future needs.

In the 25 years from 1948 to 1973, the golden age for the United States, productivity increased 2 percent each year. During the next six years, after 1973, productivity growth disappeared completely.

From 1979 to 1987, it came back a little bit, but only six-tenths of a percent, relative to the 2 percent in the previous period.

What does that mean in human terms? If you do not have productivity, you can't increase real wages, and to take one especially vulnerable group, the average age of working young men with only a high school education fell by 28 percent between 1973 and 1986. That is, the younger brother of somebody who graduated with a high school degree in 1973, if that younger brother graduated in 1986, they would be making only three-fourths as much money after tax and after inflation, and that may be some of the reasons that you see poverty in single-parent families and many other social ills.

That lack of productivity is an urgent problem today, on April 11, 1989. We are having higher wages because there are fewer young people and because of the minimum wage legislation that will be further brought along, and I have no argument with the increase in the minimum wage. I would just say that that is a fact, that we are going to have wages going up.

If productivity does not go up, if the youngsters do not serve more hamburgers or the nurses' assistants do not serve more patients, then prices go up, and, in fact, wage inflation was in evidence in the fourth quarter of last year. The result was Mr. Greenspan raising interest rates.

I do not know if the 8 percent rule that was mentioned a moment ago is an iron rule, but higher interest rates are not good for R&D or anything else, and now you have higher interest rates, and most economists are predicting an economic slowdown in the second half of this year, I would submit partially because we are not getting the productivity increases that match the wage increases, and so instead we get inflation, high interest rates, and a recession.

We are also going to have a problem in the future. That is, it is not a 1989 problem. If we look out to the future, where R&D strategy must look, to the year 2008, in 2008 the babies born in 1946 become 62. That is the average age of retirement for males today in the United States. 1946 I picked, because that is the beginning of the baby boom.

Starting in the year 2010, the percentage of the population that is 65 and over, now about 10 percent, starts to climb and gets to 20 percent as the baby boom, which put great pressure on schools and put great pressure on job markets, will put similar pressures on the retirement and health system. Those people over 65 get most of their money from other people who are under 65. They only earn about 16 percent of their income.

So the workers in the year 2010 are going to see their deductions in their paychecks go up to support this greater number of elderly. We are already seeing it in the fact that Social Security tax rates are going up in an attempt to put money away.

The Federal Government in 1985 spent $50 billion for the 6 million persons who were 80 years of age or older. The share of Medicare expenditures in GNP is expected to grow from about 2 percent now to 4.5 percent in 2030. Under pessimistic assumptions, you get to 8.5 percent just for Medicare. That is bigger than the defense budget as a share of GNP is today. And it is not only public pro-

grams, private programs are going up; 20 to 30 percent increases in health insurance premiums are common. That means it comes out of today's paycheck. So we have a problem that can only be solved by more productivity, partially because of the baby boom and then the birth dearth that came after that.

The share of the population that is of working age will fall to close to 50 percent in the 2030 to 2050 period. The rapid increase in labor force participation of women is also diminishing. All in all, we are seeing labor force growth fall from 3 percent a year to 1 percent a year. That is part of the reason the 5 percent unemployment rate was recorded last month. In reality, it means in Connecticut, in California, in New York, and New Jersey, and many other places you cannot find young people for your jobs, and, in the future, as I said, the problem is going to be worse.

Today, there are about 30 Social Security recipients for every 100 workers making contributions; in 2030, there will be 50 retirees for every 100 workers. The Social Security tax rates will go from 11.4 percent last year to 12.4 percent in 1990.

In short, because of our demographics, every worker will have to pay more for Social Security, more for pensions, more for health insurance, to support the retirees. Unless they are more productive, the take-home pay and the retirement benefits will diminish. Indeed, if productivity growth does not accelerate from the seven-tenths or so per year that we are now recording, we are going to see stagnation in this country in per capita income starting about 20 years from now. Things will not get better after 2010 for the average American unless productivity growth is accelerated.

When we think about productivity growth, we must think, I believe, about the service sector, and the nonmanufacturing sector. First, in 1983, production workers only received 6.2 percent of GNP. So if every widget maker made twice as many widgets next year as last, it would not change the problem.

The most important R&D will have to do with the service sector. That is where all of the new jobs are, according to Workforce 2000. We are going to have to increase service sector productivity because that is where the young workers are. In fact, in the last 15 years, productivity grew in manufacturing more rapidly than it did before in the golden age. All of our slowdown in productivity, more than 100 percent of it, comes from the nonmanufacturing sector.

We are not having a problem in producing more widgets per hour, we are having a problem in producing more health care per hour and more retail sales per hour.

A substantial part of the problem relates to services that are the Federal Government and local government responsibilities—health and education. Those are funded with tax dollars. If the Government were to think of itself as a business, it would look and say we are hemorrhaging in a couple of areas and we had better do some research to stop that hemorrhaging, and the health and education sectors, our human resource sectors, are key to that.

If you take health, education, and general government, in 1985 it had five million more employees than manufacturing. So surely as you look for criteria, you had better look where you are spending public dollars, I would submit.

Let's take a look at this committee. Your fiscal freedom, as many of you have mentioned this morning, is limited by the deficit. According to President Bush's budget, spending for general science, space, and technology will increase by $6.5 billion between 1989 and 1993. During that period, health care spending will go up by $20 billion if a lot of things occur in the health sector, which many people think will be unlikely. That is, that $20 billion increase takes into account a lot of savings that people are going to find difficult to bring about.

Let me try to make some of the abstractions real. Take nursing homes, an area where Congress will, I am sure, continue to put more attention over the next few years; 45 percent of the workers in nursing homes are nurses' assistants. The most recent survey that I have seen of their wages says the nurse's assistant makes only $4 an hour. Their wages are going to rise; they are going to rise whether or not you have a minimum wage, increase, because there is a shortage of people who want to do that work. If their wages rise and their productivity does not rise—the nurses' assistants do the same job—then the only thing that can happen is, costs are going to rise, and I do not believe it is going to come out of profits, it is going to come out of the Federal budget and private budgets to pay for people in nursing homes. So the only way to keep the health care costs down is to increase productivity.

R&D invested in innovative ways of teaching nurses' assistants to do their jobs could save money. If the assistants could take some of the nurses' duties, because the nurses' assistants knew more, then the nursing shortage, which I am sure all have heard about, would be somewhat diminished.

Success would reduce pressure on the Federal budget, it would lower overall inflation, and reduce the cost of health-related fringe benefits throughout the economy. Almost all, if not all, of the acceleration in wage costs last year, in the fourth quarter of last year, came, not from wages that went into workers' pockets, but came from increased payments for health insurance premiums. So all these things fit together.

The second issue that I want to deal with is the diverse population in the work place of the future, and two key words are "diversity" and "future." We have not had a shortage of capital, according to the BLS figures. That is, the capital:labor ratios are growing in the recent period as they did in the past.

In terms of years of experience or years of schooling after a slowdown, when the baby boom first came into the work force, that, too, is going up just as rapidly as it did in the golden age. There are only two likely culprits. Either we are having a lower rate of technological innovation or we have a less effective education and training system.

I think at least part of the problem has got to do with schooling. It is less valuable now than it was before because the student body has changed and the economy has changed and the education system has been slow to change in response to those.

First, we are educating a majority of minorities with an education system designed to prepare white males. Second, we are preparing all these people for a widget-making economy, not for the information service jobs of tomorrow. And when the baby boom

ended for the white population it did not end for minorities. The population growth because of that and immigration meant that the population growth among minorities was three times that of whites in the eighties, 21 percent versus 8. As a result, the majority of net new workers being added to the U.S. labor force are minorities.

I guess that is an oxymoron, to have a majority of minorities, but that is what we have; 56 percent are minorities. I am not including women in minorities. The white males are 9 percent of the net addition; that is, new workers minus retirees.

We took a look in Workforce 2000 at what the Nation would need in the year 2000 in the way of skills. We predicted productivity increases that, by the way, were more modest than those predicted in the Bush budget; 1.5 percent per year growth, about doubling from where we have been; the Bush budget in the same terms is about 1.7 percent. We used econometric models and the Wharton input/output model, and we predicted what the occupations would be in the future.

Luckily, the Department of Labor has six scale levels of what the jobs are, and we were able to predict what the skill level would be necessary in the year 2000 to get those productivity gains. That came out to 3.6 on average in the year 2000.

We were fortunate in that the Educational Testing Service, under their national assessment of educational progress, made a study of 21- to 25-year-olds, and some of the horror stories are well known. But, all in all, we found that the average 21- to 25-year-old had a skill level of 2.6 when we need 3.6. The bottom line is, we need to train 25 million people in the next decade and bring them up from 2.6 to 3.6, or 38 percent.

We can not concentrate only on the little children, though that must be done, because 80 percent of the work force of the year 2000 is already there. But we have to change the education and training system with a lot of R&D. I think the R&D spending in education is less than 1 percent of the education budget. I do not know what the figure is in defense, but it is considerably more than 1 percent.

We must change the curriculum. You have to change the teaching methodologies. And, also important but often ignored, we have to change the way progress is measured. Everybody calls for accountability, but we do not know what we are accounting for. We have to teach people how to solve problems and test their capacity to solve novel problems. They have to transfer the K through 12 system as well as the adult education system.

If you remember back to old movies, Dustin Hoffman was told in "The Graduate" that the future was in plastics. I do not think that it is in plastics any more, I think the biggest payoff for the Nation will be in learning how humans think and how to teach them effectively. Why is that? Because, as an economist, you look where the shortages are, and there is going to be a shortage of capable workers in the United States over the next quarter-century.

I would suggest three areas for Federal support of basic and applied research and technology development. One, the cognitive sciences: How do people learn to solve problems? And I mean by that, how do different people learn to solve problems? One size does not fit all, and we will need to have different approaches for different folks. Second, in learning technology: How can machines be used to

teach? I am all interested in high-density TV, but I have a different level of interest if it is an entertainment medium than if it is an education medium, and the Federal Government's primary responsibility, in my judgment, has to be towards the learning situation, not towards the entertainment side, which will take care of itself.

And the third thing, a very modest amount of money, there needs to be money spent in evaluation methodologies. How can we tell if we are doing things right if we have no yardsticks? And I think the Federal Government has a role in providing those yardsticks.

It is really too late to do much about this year's economy or next year's economy, but it is not too late to change productivity in 1995 or the year 2000. It is going to require political leadership, public-private partnerships, intelligent use of the five to seven billion now being spent in programs such as JTPA, welfare reform, immigration reform, and educational education, programs, by the way, that have essentially no R&D budget; five to seven billion dollars a year and no R&D budget of any size. And solutions are going to require long-term investments in the forgotten half of our population that does not go to college. I know the committee is very interested in science, scientists, and Ph.D.'s, but the relative investment in those people is quite high compared to the half that are not fortunate enough to go to college.

Thank you.

[The prepared statement of Dr. Packer, plus the summary follow:]

TESTIMONY

OF

DR. ARNOLD H. PACKER

SENIOR RESEARCH FELLOW

HUDSON INSTITUTE

April 11, 1989

before the

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE,

AND TECHNOLOGY

Room 2318

Rayburn House Office Building

MR. CHAIRMAN: IT IS A PLEASURE AND HONOR TO TESTIFY BEFORE YOU TODAY.

YOUR LETTER OF INVITATION ASKED FOR MY VIEWS ON THE FEDERAL GOVERNMENT'S R&D STRATEGY IN LIGHT OF OUR CHANGING DEMOGRAPHIC AND ECONOMIC SITUATION. AS YOU MAY KNOW, BILL JOHNSTON, MY COLLEAGUE AT THE HUDSON INSTITUTE, AND I WROTE A BOOK ENTITLED WORKFORCE 2000. THE EXECUTIVE SUMMARY, WHICH I WILL SUBMIT FOR THE RECORD, CARRIES A FEW RECOMMENDATIONS THAT RELATE TO THIS ISSUE. IN SHORT, WE NEED TO LEARN HOW BETTER TO:

1. INCREASE PRODUCTIVITY IN THE SERVICE SECTOR AND ESPECIALLY IN GOVERNMENT-FINANCED SERVICES, SUCH AS EDUCATION AND HEALTH AND
2. EDUCATE AND TRAIN A DIVERSE POPULATION FOR THE WORKPLACE OF THE FUTURE.

THE NEED FOR INCREASING SERVICE SECTOR PRODUCTIVITY

OUR PRODUCTIVITY PERFORMANCE OVER THE LAST 15 YEARS HAS BEEN ABYSMAL. THE AMOUNTS OF GOODS AND SERVICES PRODUCED BY THE AVERAGE WORKER HAS NOT INCREASED RAPIDLY ENOUGH. THAT JUDGMENT IS ACCURATE WHETHER THE COMPARISON IS MADE TO EARLIER PERIODS, TO OUR INTERNATIONAL COMPETITORS, OR TO OUR CURRENT OR FUTURE NEEDS. IN THE 25 YEARS FROM 1948 TO 1973, THE SO CALLED GOLDEN AGE, MULTI-

FACTOR PRODUCTIVITY IN THE PRIVATE SECTOR INCREASED 2.0% ANNUALLY. DURING THE NEXT 6 YEARS GROWTH DISAPPEARED AND FROM 1979 TO 1987, MULTI-FACTOR PRODUCTIVITY INCREASED ONLY 0.6% ANNUALLY.

WHAT DOES THE PRODUCTIVITY-GROWTH SLOWDOWN MEAN IN HUMAN TERMS? REAL WAGES -- WAGE RATES ADJUSTED FOR INFLATION -- CANNOT INCREASE UNLESS OUTPUT PER WORKER INCREASES. SO, BETWEEN 1973 AND 1986 THE AVERAGE WAGE OF WORKING YOUNG MEN WITH ONLY A HIGH SCHOOL EDUCATION FELL BY 28%. THAT MAY BE PART OF THE REASON FOR INCREASED POVERTY, SINGLE-PARENT FAMILIES, AND ASSOCIATED SOCIAL ILLS.

THE LACK OF PRODUCTIVITY GROWTH IS AN URGENT PROBLEM TODAY, IN APRIL OF 1989. HIGHER WAGES, MATCHED BY INCREASING OUTPUT PER WORKER (I.E., YOUNGSTERS SERVING MORE HAMBURGERS AND NURSES ASSISTANTS SERVING MORE PATIENTS), WILL LEAD TO A BALANCED BUDGET AND REDUCED POVERTY. WITHOUT PRODUCTIVITY INCREASES FOOD PRICES, HEALTH CARE COSTS AND THE PRICES OF OTHER GOODS AND SERVICES ARE ON THEIR WAY UP. INFLATION IS APPROACHING THE 5% RATE.

WAGE RATES ARE INCREASING FOR ECONOMIC AND DEMOGRAPHIC REASONS THAT I WILL DISCUSS LATER. BECAUSE PRODUCTIVITY HAS NOT INCREASED EQUALLY, WAGE COSTS HAVE INCREASED. THAT EARLY SIGN OF INFLATION LED FRB CHAIRMAN GREENSPAN TO INCREASE INTEREST RATES OVER THE LAST YEAR. AS A RESULT, THE SALES OF AUTOS AND HOMES HAVE FALLEN AND AN ECONOMIC SLOWDOWN IS WIDELY EXPECTED IN THE SECOND HALF OF THIS YEAR.

BECAUSE OF DEMOGRAPHICS, THE LACK OF PRODUCTIVITY GROWTH WILL BE A PROBLEM IN THE FUTURE. THE BABY BOOM RAN FROM 1946 TO 64.

IN THE YEAR 2008, THE 1946 BABIES TURN 62, THE AVERAGE AGE THAT MALES ARE RETIRING TODAY. STARTING IN 2010, THE PERCENTAGE OF THE POPULATION THAT IS 65 AND OVER (NOW ABOUT 10%) BEGINS TO RISE AT A RAPID RATE UNTIL IT LEVELS OFF NEAR 20% IN 2030 WHEN THE YOUNGEST OF THE BABY BOOMERS CELEBRATE THEIR 68TH BIRTHDAY. TODAY, THOSE OVER 65 EARN ONLY ABOUT 16% OF THEIR INCOME. THEY RECEIVE THE REMAINING 84% OF THEIR INCOME FROM INTER-GENERATIONAL TRANSFERS OF ONE SORT OR ANOTHER -- 38% FROM SOCIAL SECURITY, 28% FROM ASSETS, AND 14% FROM PENSIONS.

NOT ONLY WILL WORKERS IN THE EARLY PART OF THE NEXT CENTURY HAVE TO SUPPORT MORE AGED, THEY WILL HAVE TO PAY INCREASING AMOUNTS FOR HEALTH EXPENDITURES FOR THE AGED AND ESPECIALLY FOR THE VERY OLD. IN 1985, THE FEDERAL GOVERNMENT SPENT A REPORTED $50 BILLION FOR THE SIX MILLION PERSONS WHO WERE 80 YEARS OF AGE OR OLDER. THE SHARE OF MEDICARE EXPENDITURES IN GNP IS EXPECTED TO GROW FROM 2.1% OF GNP IN 1990 TO 4.5% IN 2030. UNDER PESSIMISTIC ASSUMPTIONS THE SHARE COULD AMOUNT TO 8.5% OF GNP IN 2030. MEANWHILE, ANNUAL INCREASES OF 20 AND 30% FOR PRIVATE HEALTH INSURANCE PREMIUMS ARE COMMON IN 1989.

THE NEED FOR MORE PRODUCTIVITY AND MORE SKILLS STEMS NOT ONLY FROM THE "EXCESS" OF 1946-62 BIRTHS BUT FROM THE ABSENCE OF BIRTHS IN THE FOLLOWING YEARS; I.E., FROM THE SO-CALLED "BIRTH DEARTH." SIMULTANEOUS WITH THE INCREASING SHARE OF POST 65-YEAR-OLDS IN THE 2030-50 PERIOD, THE SHARE OF THE POPULATION THAT IS OF WORKING AGE FALLS UNTIL IT IS NOT MUCH ABOVE 50%. ALSO, THE RAPID INCREASE IN LABOR FORCE PARTICIPATION BY WOMEN IS SLOWING. AS A RESULT OF

THESE CHANGES, LABOR FORCE GROWTH IS SLOWING FROM AN AVERAGE OF 3% ANNUALLY IN THE 1970'S TO AN ESTIMATED 1% IN THE 1990'S. LABOR FORCE GROWTH IS PROJECTED TO DISAPPEAR COMPLETELY EARLY IN THE NEXT CENTURY UNDER CURRENT DEMOGRAPHIC TRENDS.

IN SUMMARY, THE GROWING NUMBER OF RETIREES WILL HAVE TO BE SUPPORTED BY RELATIVELY FEWER ACTIVE WORKERS. TODAY, THERE ARE ABOUT 30 SOCIAL SECURITY RECIPIENTS FOR EVERY 100 WORKERS MAKING PAYROLL TAX CONTRIBUTIONS. BY 2030 THERE WILL BE 50 (SSA SCENARIO II-B) FOR EVERY 100. WE ARE ALREADY SEEING THE EFFECTS OF THE DEMOGRAPHIC TRENDS ON PAYCHECKS; SOCIAL SECURITY TAX RATES WILL CONTINUE TO INCREASE (THE RATES INCREASE FROM 11.4% IN 1988 TO 12.4% IN 1990), FURTHER DIMINISHING TAKE-HOME PAY.

WITH THESE DEMOGRAPHICS EVERY WORKER WILL HAVE TO PAY MORE FOR SOCIAL SECURITY, PENSIONS AND HEALTH INSURANCE TO SUPPORT RETIREES. UNLESS THE ACTIVE WORKERS BECOME MORE PRODUCTIVE THAN THEY ARE NOW, EITHER TAKE-HOME PAY OR RETIREMENT BENEFITS (OR BOTH) WILL DECLINE. INDEED, IF PRODUCTIVITY GROWTH DOES NOT ACCELERATE, STAGNATION IN PER CAPITA INCOME IS LIKELY IN 20 YEARS. O U R THINKING ABOUT PRODUCTIVITY GROWTH MUST RECOGNIZE THE GROWING IMPORTANCE OF THE SERVICE AND OTHER NON-MANUFACTURING SECTORS. FEWER AND FEWER OF US ARE IN THE WIDGET-MAKING BUSINESS, MORE AND MORE OF US ARE PROVIDING HEALTH AND BUSINESS SERVICES OR WORKING IN RETAIL STORES. BY 1983, PRODUCTION WORKERS ONLY RECEIVED, AS WAGES, 6.2% OF GNP. IN THE EARLIER INDUSTRIAL AGE, R&D USUALLY MEANT PRODUCTS, E.G., A BETTER WIDGET.

IN THE FUTURE THE MOST ECONOMICALLY IMPORTANT R&D WILL MEAN

BETTER SERVICES. THAT IS WHERE ALL THE NEW JOBS WILL BE. THE ONLY WAY THAT THESE NEW JOBS WILL BE GOOD JOBS IS TO MAKE THEM PRODUCTIVE. SERVICE SECTOR WAGES WILL INCREASE BECAUSE OF THE SHORTAGE OF YOUNG WORKERS. ONLY PRODUCTIVITY INCREASES CAN KEEP THE WAGE INCREASES FROM BEING INFLATIONARY.

WHY DO I BLAME THE PRODUCTIVITY SLOWDOWN OF THE LAST 15 YEARS, THE SLOWDOWN IN NON-MANUFACTURING PRODUCTIVITY? BECAUSE PRODUCTIVITY GROWTH IN MANUFACTURING IN THE 1979-87 PERIOD WAS ACTUALLY HIGHER (2.6% ANNUALLY) THAN IT WAS IN THE 25 YEAR GOLDEN AGE (GROWTH IN MANUFACTURING PRODUCTIVITY WAS 2% ANNUALLY DURING 1948-73).

A SUBSTANTIAL PART OF THE PROBLEM LIES WITH THOSE SERVICES THAT ARE MOSTLY FINANCED WITH TAX DOLLARS; NAMELY HEALTH, EDUCATION, AND GENERAL GOVERNMENT SERVICES WHICH, TOGETHER, HAD 5 MILLION MORE EMPLOYEES THAN MANUFACTURING IN 1985. SURELY, FEDERAL R&D STRATEGY SHOULD INCLUDE IMPROVING PRODUCTIVITY IN THIS PUBLIC SECTOR.

LET ME EXPLAIN. THIS COMMITTEE'S FISCAL FREEDOM, LIKE ALL OTHER COMMITTEES IN CONGRESS, IS RESTRICTED BY THE DEFICIT. ACCORDING TO THE PRESIDENT'S BUDGET, SPENDING FOR GENERAL SCIENCE, SPACE, AND TECHNOLOGY WILL INCREASE BY $6.5 BILLION BETWEEN 1989 AND 1993. DURING THAT PERIOD SPENDING FOR HEALTH CARE WILL INCREASE BY $20 BILLION AND THAT INCLUDES CONTROVERSIAL SAVINGS IN HOSPITAL AND PHYSICIAN COSTS. R&D THAT SAVED HEALTH DOLLARS WOULD FREE DOLLARS FOR OTHER PURPOSES.

AN EXAMPLE WILL MAKE THESE ABSTRACTIONS REALISTIC. ABOUT 45%

OF WORKERS IN NURSING HOMES ARE NURSES ASSISTANTS AND THEIR AVERAGE WAGE IS ONLY $4.00 AN HOUR ACCORDING TO A RECENT SURVEY OF THE AMERICAN HEALTH CARE ASSOCIATION. THEIR WAGES ARE RISING AND WILL RISE FURTHER BECAUSE OF THE WORKER SHORTAGE AND INCREASING NEED (BOTH A RESULT OF CHANGING DEMOGRAPHICS) AND THE PENDING INCREASE IN THE MINIMUM WAGE. HEALTH CARE COSTS WILL INCREASE UNLESS THE PRODUCTIVITY OF WORKERS ASSISTANTS IS INCREASED. THEY NEED TO PROVIDE MORE AND BETTER SERVICE.

R&D, USEFULLY INVESTED IN INNOVATIVE WAYS OF TEACHING NURSES ASSISTANTS TO DO THEIR JOBS BETTER WOULD SAVE MONEY. FOR EXAMPLE, IF THE ASSISTANTS COULD TAKE OVER SOME NURSING DUTIES, BOTH ASSISTANTS AND NURSES WOULD HAVE BETTER JOBS AND THE SYSTEM WOULD BE BETTER ABLE TO SUSTAIN THE NURSING SHORTAGE. SUCCESS WOULD REDUCE PRESSURE ON THE FEDERAL BUDGET, LOWER OVERALL INFLATION, AND REDUCE THE COST OF HEALTH-RELATED FRINGE BENEFITS THROUGHOUT THE ECONOMY.

UPGRADING A DIVERSE POPULATION FOR THE WORKPLACE OF THE FUTURE.

THE CAUSES OF THE PRODUCTIVITY SLOWDOWN ARE CONTROVERSIAL. BLS FIGURES SHOW NO DETERIORATION IN THE CAPITAL LABOR RATIO. RECENT STUDIES INDICATE THAT, IN TERMS OF YEARS OF EXPERIENCE AND YEARS OF SCHOOLING, THE U.S. WORKFORCE IS IMPROVING AS RAPIDLY NOW AS IT DID IN THE GOLDEN YEARS. SO THE PRODUCTIVITY SLOWDOWN MUST COME FROM A LOWER RATE OF TECHNOLOGICAL INNOVATION OR FROM A LESS EFFECTIVE EDUCATION AND TRAINING SYSTEM.

MY GUESS IS THAT SCHOOLING IS LESS VALUABLE NOW BECAUSE THE STUDENT BODY AND THE ECONOMY HAVE CHANGED MUCH MORE QUICKLY THAN THE EDUCATION AND TRAINING SYSTEM HAVE ADAPTED TO THESE NEW REALITIES. FIRST, WE ARE EDUCATING A "MAJORITY OF MINORITIES" WITH AN EDUCATION SYSTEM DESIGNED TO PREPARE WHITE MALES. SECOND, WE ARE PREPARING STUDENTS FOR YESTERDAY'S WIDGET-MAKING ECONOMY, NOT THE INFORMATION/SERVICE JOBS OF TOMORROW.

AFTER THE BABY BOOM, FERTILITY FOR "MINORITIES" REMAINED HIGH LONGER THAN FOR WHITES. IN ADDITION, IMMIGRATION OF MINORITIES REMAINED HIGH. POPULATION GROWTH AMONG MINORITIES HAS BEEN ALMOST THREE TIMES THAT OF WHITES (21% VS 8% IN THE 1980'S). THUS, THE SHARE OF MINORITIES AMONG ENTRY LEVEL WORKERS HAS INCREASED WHILE WHITE WORKERS HAVE RETIRED. AS A RESULT, THE MAJORITY OF NET NEW WORKERS BEING ADDED TO THE U.S. LABOR FORCE ARE "MINORITIES." BETWEEN 1986 AND 2000, 56% OF THE NET ADDITIONS TO THE U.S. WORKFORCE WILL BE MINORITIES. (NET ADDITIONS IS THE DIFFERENCE BETWEEN NEW ENTRANTS AND RETIREES. THE LARGE NUMBER OF RETIRING WHITE MEN IS PARTLY RESPONSIBLE FOR THE FACT THAT ONLY 9% OF THE NET NEW WORKERS ARE WHITE MALES.)

TOMORROW'S SKILL REQUIREMENTS WERE PROJECTED IN HUDSON INSTITUTE'S WORK FORCE 2000 REPORT. OUR BASE CASE PROJECTS GROWTH OF 2.9% ANNUALLY OVER THE 1985-2000 PERIOD, WHILE THE BUDGET AND CURRENT ACCOUNT DEFICITS ARE ELIMINATED. USING THE INPUT/OUTPUT TABLES OF THE WHARTON ECONOMETRIC MODEL, PROJECTIONS WERE ALSO MADE OF OUTPUT AND EMPLOYMENT IN THE VARIOUS MANUFACTURING AND SERVICE INDUSTRIES THAT CONSTITUTE THE U.S. ECONOMY. IN THIS WAY, WE

PROJECTED THE OCCUPATIONS OF THE U.S. WORKFORCE IN THE YEAR 2000.

THE U.S. DEPARTMENT OF LABOR (DOL) HAS ESTIMATED THE WORKPLACE SKILLS, FROM BASIC THROUGH ADVANCED, NEEDED IN EACH OF THE 12,000 JOBS IN THE DICTIONARY OF OCCUPATIONAL TITLES. THEY HAVE ESTABLISHED A LANGUAGE AND A MATH SCALE, EACH CONTAINING SIX LEVELS, AND ASKED EMPLOYERS AND SUPERVISORS TO RATE THE REQUIREMENTS OF EACH JOB. (TABLE I IS A BRIEF DESCRIPTION OF THE DEPARTMENT OF LABOR'S LANGUAGE SCALE.) THESE SKILL REQUIREMENTS WERE APPLIED TO OBTAIN PROJECTIONS OF SKILLS REQUIRED IN THE YEAR 2000 IF THE PRODUCTIVITY AND ECONOMIC PROJECTIONS ARE TO BE REALIZED.

OUR NEXT STEP WAS TO COMPARE THE SKILLS OF THE NATION'S WORKFORCE TO THE DEMANDS OF THE JOBS THAT SUCH AN ECONOMY WOULD GENERATE. FORTUNATELY, THE EDUCATIONAL TESTING SERVICES' (ETS) HAD MADE THE NEEDED SURVEY OF THE SKILLS OF YOUNG PEOPLE. THEIR RECENT NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS (NAEP) LITERACY, PROFILES OF AMERICA'S YOUNG ADULTS, WAS AN IMPORTANT EXTENSION OF ETS'S USUAL ANALYSIS OF THE ACADEMIC ACHIEVEMENT OF SCHOOL-AGE STUDENTS. ETS SURVEYED 3600 21-TO-25-YEAR-OLDS TO DETERMINE THEIR PROSE, DOCUMENT, AND NUMERICAL LITERACY SKILLS AND FOUND THAT MOST OF THOSE SURVEYED POSSESSED BASIC LITERACY, BUT NOT HIGHER ORDER SKILLS.

COMPARING THE NAEP SURVEY TO THE WORK FORCE 2000 PROJECTIONS PROVIDES A CONSERVATIVE ESTIMATE THAT 25 MILLION WORKERS NEED TO UPGRADE THEIR BASIC WORKPLACE SKILLS IN THE DECADE OF THE 1990'S,

IF THE WORK FORCE 2000 PRODUCTIVITY GOALS ARE TO BE MET.

IN ADDITION TO KNOWING HOW MANY STUDENTS NEED TRAINING, WE ESTIMATED THE TRAINING NEEDED BY THE AVERAGE STUDENT (E.G., A WEEK'S BRUSH UP IN MATH OR A FOUR-YEAR BASIC EDUCATION?). WE FOUND THAT THE AVERAGE SKILL LEVEL FROM THE NAEP SURVEY WAS 2.6 ON THE DOL SCALE, SUBSTANTIALLY LESS THAN THE 3.6 SKILL LEVEL REQUIRED OF THE 26 MILLION NET NEW JOBS THAT WORK FORCE 2000 PROJECTS WILL BE ADDED BETWEEN 1985 AND 2000.

THUS, 25 MILLION WORKERS REQUIRE AN AVERAGE UPGRADING OF 38%. THE GREATEST NUMBER OF UPGRADES ARE NOT THE LOWEST LEVEL WORKERS BUT, RATHER, THOSE IN BETWEEN THE SECOND AND THIRD STEPS OF THE DEPARTMENT OF LABOR'S SIX-STEP SKILL LEVEL.

OVER 80% OF THE YEAR 2000 WORKFORCE IS ALREADY IN THE LABOR FORCE. THE IMPROVEMENT IN BASIC SKILLS OF 25 MILLION ADULTS NEEDS TO START IMMEDIATELY AS THE PRODUCTIVITY OF THE EDUCATION/TRAINING SYSTEM ITSELF IS INCREASED. EMPHASIS MUST BE PLACED ON THE WAY EDUCATION AND TRAINING IS PROVIDED -- THE CURRICULUM, THE TEACHING METHODOLOGIES, AND THE WAY IN WHICH PROGRESS IS MEASURED. OUR SCHOOLS AND TRAINING INSTITUTIONS ALREADY "SERVE" ENOUGH STUDENTS, BUT SERVE THEM NOT VERY WELL.

THE K-12 SYSTEM MUST BE TRANSFORMED IN THE NEXT 10 TO 20 YEARS OR THE ADULT SYSTEM WILL BE OVERWHELMED. THE SITUATION HAS BEEN LIKENED TO BAILING A BOAT WITH A BIG HOLE IN ITS BOTTOM. THERE IS ENOUGH TIME TO AFFECT THE HIGH-SCHOOL GRADUATING CLASS OF 2001, IF CHANGE IS BEGUN SOON. BY 2010 WE NEED A LABOR FORCE THAT IS MUCH MORE PRODUCTIVE THAN TODAY'S, AND ONE THAT CONTINUES TO IMPROVE

DURING THE 2010-30 PERIOD WHEN THE BABY BOOM RETIRES.

R&D PRIORITIES

THE MOST ECONOMICALLY IMPORTANT R&D IN THE FUTURE IS UNLIKELY TO BE ELECTRONICS OR ANY MANUFACTURING TECHNOLOGY. THE FUTURE IS NOT IN PLASTICS, AS ANNE BANCROFT TOLD DUSTIN HOFFMAN IN THE GRADUATE, BUT IN SERVICES.

MY GUESS IS THAT THE BIGGEST PAYOFF WILL COME FROM LEARNING HOW HUMANS THINK AND HOW TO TEACH THEM EFFECTIVELY. WHY? BECAUSE CAPABLE WORKERS WILL BE IN SHORT SUPPLY OVER THE NEXT TWENTY-FIVE YEARS.

THUS, I SUGGEST THE FOLLOWING THREE AREAS FOR FEDERAL SUPPORT OF BASIC AND APPLIED RESEARCH AND TECHNOLOGY DEVELOPMENT:

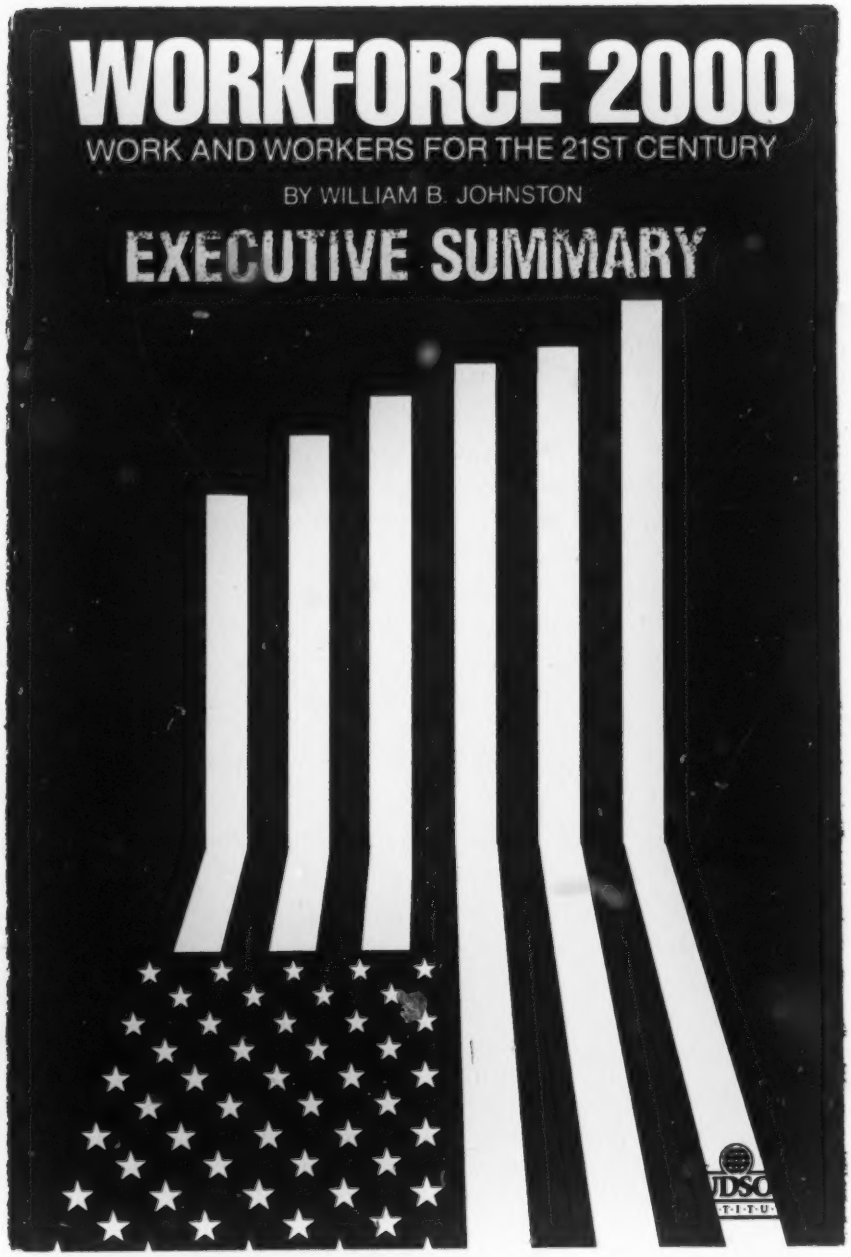
-O- THE COGNITIVE SCIENCES -- HOW DO PEOPLE LEARN TO SOLVE PROBLEMS,

-O- LEARNING TECHNOLOGY -- HOW CAN MACHINES BE USED TO TEACH, AND

-O- EVALUATION METHODOLOGIES -- HOW CAN WE TELL IF WE ARE DOING THINGS RIGHT.

IT IS TOO LATE TO DO MUCH ABOUT 1989 OR 1990'S ECONOMY. BUT IT IS NOT TOO LATE TO CHANGE PRODUCTIVITY IN 1995 OR 2000. REMEDIES WILL REQUIRE POLITICAL LEADERSHIP, PUBLIC-PRIVATE PARTNERSHIPS, INTELLIGENT USE OF THE $5 TO $7 BILLION NOW BEING SPENT IN PROGRAMS SUCH AS JTPA, WELFARE REFORM, IMMIGRATION REFORM, AND VOCATIONAL EDUCATION -- AND EFFECTIVE R&D. SOLUTIONS REQUIRE LONG TERM INVESTMENTS IN THE FORGOTTEN HALF OF OUR POPULATION THAT DO NOT MAKE IT TO COLLEGE.

THE PROBLEMS OF ALL AGES -- FROM PRE-SCHOOLERS TO THEIR MOMS AND INCLUDING WORKERS DISLOCATED BY ECONOMIC CHANGE -- NEED ATTENTION. IT IS TOO LATE TO CONCENTRATE ONLY ON PRE-SCHOOLERS, OR TO LIMIT EFFORTS TO A PILOT HERE AND THERE. THE GOALS SHOULD BE UPGRADING 25 MILLION WORKERS DURING THE 1990'S AND CONQUERING ILLITERACY BY 2010.


WORKFORCE 2000
WORK AND WORKERS FOR THE 21ST CENTURY
BY WILLIAM B. JOHNSTON
EXECUTIVE SUMMARY

WORKFORCE 2000
EXECUTIVE SUMMARY

The year 2000 will mark the end of what has been called the American century. Since 1900, the United States has become wealthy and powerful by exploiting the rapid changes taking place in technology, world trade, and the international political order. The last years of this century are certain to bring new developments in technology, international competition, demography, and other factors that will alter the nation's economic and social landscape. By the end of the next decade, the changes under way will produce an America that is in some ways unrecognizable from the one that existed only a few years ago.

Four key trends will shape the the last years of the twentieth century:

- *The American economy should grow at relatively healthy pace,* boosted by a rebound in U.S. exports, renewed productivity growth, and a strong world economy.
- Despite its international comeback, *U.S. manufacturing will be a much smaller share of the economy in the year 2000* than it is today. Service industries will create all of the new jobs, and most of the new wealth, over the next 13 years.
- *The workforce will grow slowly, becoming older, more female, and more disadvantaged.* Only 15 percent of the new entrants to the labor force over the next 13 years will be native white males, compared to 47 percent in that category today.
- *The new jobs in service industries will demand much higher skill levels* than the jobs of today. Very few new jobs will be created for those who cannot read, follow directions, and use mathematics. Ironically, the demographic trends in the workforce, coupled with the higher skill requirements of the economy, will lead to both higher and lower unemployment: more joblessness among the least-skilled and less among the most educationally advantaged.

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These trends raise a number of important policy issues. If the United States is to continue to prosper—if the year 2000 is to mark the end of the *first* American century—policymakers must find ways to:

- *Stimulate Balanced World Growth*: To grow rapidly, the U.S. must pay less attention to its share of world trade and more to the growth of the economies of the other nations of the world, including those nations in Europe, Latin America, and Asia with whom the U.S. competes.
- *Accelerate Productivity Increases in Service Industries*: Prosperity will depend much more on how fast output per worker increases in health care, education, retailing, government, and other services than on gains in manufacturing.
- *Maintain the Dynamism of an Aging Workforce:* As the average age of American workers climbs toward 40, the nation must insure that its workforce and its institutions do not lose their adaptability and willingness to learn.
- *Reconcile the Conflicting Needs of Women, Work, and Families:* Three-fifths of all women over age 16 will be at work in the year 2000. Yet most current policies and institutions covering pay, fringe benefits, time away from work, pensions, welfare, and other issues were designed for a society in which men worked and women stayed home.
- *Integrate Black and Hispanic Workers Fully into the Economy:* The shrinking numbers of young people, the rapid pace of industrial change, and the ever-rising skill requirements of the emerging economy make the task of fully utilizing minority workers particularly urgent between now and 2000. Both cultural changes and education and training investments will be needed to create real equal employment opportunity.
- *Improve the Educational Preparation of All Workers:* As the economy grows more complex and more dependent on human capital, the standards set by the American education system must be raised.

The U.S. Economy in the Year 2000

Because long-range forecasts are so uncertain, alternative scenarios are useful to help to bracket a range of possible outcomes. The three scenarios presented here are based not only on different rates of economic growth, but on different policy choices.

The baseline or "surprise-free" scenario reflects a modest improvement in the rate of growth that the nation experienced between 1970 and 1985. But despite improved trends in inflation and productivity, the U.S. economy does not return to the boom times of the

1950s and 1960s. Slow labor force growth is only partly offset by faster productivity gains, and imperfect coordination between the world's governments leads to only moderate rates of world growth. Economic turbulence causes periodic recessions in the U.S. that hold total growth to just under three percent per year.

In contrast, "world deflation" focuses on the possibility that a worldwide glut of labor and production capacity in food, minerals, and manufactured products could lead to a sustained price deflation and sluggish economic growth. World governments, chastened by a decade and a half of inflation, are slow to recognize the new economic realities and unwilling to undertake coordinated efforts to respond to them. The U.S., whose huge trade deficit has been the world's growth engine during the early 1980s, moves toward balance in its trade and fiscal accounts. Without U.S. stimulus, the rest of the world slides into a series of recessions that lead to increased protectionism and beggar-thy-neighbor trade, monetary, and fiscal policies that hold growth to only 1.6 percent per year over the period.

The third scenario, the "technology boom," outlines a powerful rebound in U.S. economic growth to levels that compare with the first two decades following World War II. Coordinated international monetary, fiscal, and trade policies succeed in smoothing world business cycles. Renewed public and private lending to developing nations and low oil prices trigger rapid growth in much of the Third World. In the U.S., high rates of investment in both physical and human capital, coupled with rapid productivity growth in services, low inflation, low resource prices, lower taxes, and less government intervention combine to produce a boom in productivity that causes the U.S. economy to surge ahead by 4 percent per year.

Table 1 summarizes the major assumptions and outcomes of the three scenarios. The table underscores several key points about the U.S. economy over the next 13 years:

- *U.S. Growth and World Growth are Tightly Linked:* The strong historical correlation between world growth and U.S. growth continues through the balance of the century. In the baseline forecast, the U.S. grows at about 2.9 percent, compared to 3.1 percent for the world.

Table 1
THE U.S. ECONOMY IN THE YEAR 2000

	1985 Level	2000 (Three Scenarios) BASE Level	BASE Change*	LOW Level	LOW Change*	HIGH Level	HIGH Change*
World GDP (bill. 82$)	7745	12204	3.1%	9546	1.4%	13057	3.5%
U.S. GNP (bill. 82$)	3570	5463	2.9%	4537	1.6%	6431	4.0%
GNP Deflator (1982-100)	111.7	182.4	3.3%	117.8	0.4%	196.4	3.8%
Employment (millions)	107.2	131.0	1.3%	122.4	0.9%	139.9	1.8%
Manufacturing	19.3	17.2	-0.8%	18.0	-0.4%	18.1	-0.4%
Commercial & Other Services	62.0	84.3	2.1%	76.5	1.4%	88.7	2.4%
Productivity (output/worker,82$)	33.3	41.7	1.5%	37.1	0.7%	46.0	2.2%
Manufacturing	40.4	71.4	3.9%	58.0	2.5%	81.3	4.8%
Commercial & Other Services	29.9	34.1	0.9%	30.4	0.1%	38.2	1.6%
Fed. Surplus (bill. curr.$)	-200.8	-110.0	—	-170.1	—	-40.7	—
Curr. Acct. Bal. (bill. curr.$)	-116.8	14.0	—	12.5	—	32.6	—
Disp. Income Per Capita (thou. 82$)	10.5	13.5	1.7%	11.5	0.6%	15.6	2.7%

*Average Annual Gain
Source: Hudson Institute.

• *U.S. Manufacturing Employment Declines While Services Grow:* Despite strong export growth and substantial production increases, manufacturing jobs decline in all scenarios. Whether the U.S. and world economies are booming in an open trading environment or growing slowly in an atmosphere of protectionism and nationalistic trading patterns, U.S. manufacturing jobs decrease. No pattern of growth enables manufacturing employment to return to the peak of 1979.

In addition to the decline in employment, manufacturing will decline as a share of GNP, measured in current dollars. Where manufacturing produced some 30 percent of all goods and services in 1955, and 21 percent in 1985, its share will drop to less than 17 percent by 2000.

The shift to services will bring with it broad changes in the location, hours, and structure of work. Service jobs tend to be located where and when the customer wants them, rather than centralized as are manufacturing jobs. Partly as a result, the typical workplace in the future will have fewer people, and the average workweek will become shorter with more people employed part-time.

The shift to services will also have great impacts on the economy and its employees. For example, the business cycle should moderate, since service industry growth is less volatile than manufacturing. Wages may become less equally distributed, since service jobs tend have more high and low earners, and fewer in the middle. Economic growth may be harder to achieve, because productivity gains are lower in most service industries.

Most importantly, the shift to services means that efforts to preserve or develop the nation's manufacturing base are swimming upstream against a powerful tide. Productivity gains, not Japanese competition, will gradually eliminate manufacturing jobs. Lower prices (relative to services) will gradually shrink manufacturing's share of the economy. Just as agriculture lost its central role in the American economy at the beginning of the century, so will manufacturing lose economic importance as the century draws to a close. Those who fail to recognize these inevitable trends—for example, states that try to capture new factories to boost their local economies or the Congress, which is threatening to legislate trade barriers to hang on to U.S. manufacturing jobs—will miss the most important opportunities of the future.

• *The Key to Domestic Economic Growth is a Rebound in Productivity, Particularly in Services:* Throughout the 1970s and early 1980s, the United States managed to sustain a rising standard of living by

increasing the number of people at work and by borrowing from abroad and from the future. These props under the nation's consumption will reach their limits before the end of the century: there will be relatively fewer young people and homemakers who will enter the workforce during the 1990s, and the burden of consumer, government, and international debt cannot be expanded indefinitely. If the U.S. economy is to grow at its historic 3 percent per year average, the nation must substantially increase its productivity.

Output per worker during the 1990s is projected to double, from 0.7 percent per year to 1.5 percent, the same rate as the 1960s. A combination of older, more stable, and better-educated workers, and higher rates of investment will support this improvement. Better productivity performance by the service industries will be particularly important. Output per worker in manufacturing continues to show strong gains, but the most important productivity improvements come in services, where output per worker climbs from -0.2 percent over the last 15 years to +0.9 percent per year from 1985 to 2000. The keys to such advances will be more competition in traditionally noncompetitive industries such as education, health care, and government services, coupled with the application of advanced technologies to deliver more automated business, government, and personal services.

- *U.S. Trade Accounts Move Toward Balance:* Although the different scenarios show widely dispersed rates of growth of imports and exports, the U.S. current account balance improves under all conditions. This is due both to the devaluation of the dollar that has already taken place against other currencies and to improving productivity in manufacturing industries. Under the baseline scenario, by the year 2000 the U.S. current account balance is in the black by some $14 billion.

- *The U.S. Budget Deficit Declines:* Along with the improvement in the trade deficit comes a decline in the budget deficit. Even without any major tax increases, growth in GNP and a large surplus in the Social Security Trust Fund cut the federal budget deficit to $18 billion by 1995.

- *Inflation Moderates:* Under the baseline scenario, prices increase by an average of 3.3 percent per year over the 1985–2000 period. The excess world capacity in labor, goods, and services prevents inflation from resuming its pace of the 1970s.

• *Unemployment Remains Stubbornly High:* The baseline scenario forecasts unemployment at just over 7 percent in the year 2000, despite the relatively slow growth of the labor force projected over the period. In the deflation scenario, unemployment climbs above 9 percent, while even in the boom scenario unemployment is reduced only to 5.9 percent.

• *Disposable Income Increases Moderately:* Disposable personal income per person, the best single measure of how rapidly society is improving its standard of living, grows by 1.7 percent per year under the baseline scenario, almost precisely the rate at which it grew between 1970 and 1985.

Workers and Jobs in the Year 2000

Changes in the economy will be matched by changes in the workforce and the jobs it will perform. Five demographic facts will be most important:

• *The population and the workforce will grow more slowly than at any time since the 1930s:* Population growth, which was climbing at almost 1.9 percent per year in the 1950s, will slump to only 0.7 percent per year by 2000; the labor force, which exploded by 2.9 percent per year in the 1970s, will be expanding by only 1 percent annually in the 1990s. These slow growth rates will tend to slow down the nation's economic expansion and will shift the economy more toward income-sensitive products and services (e.g., luxury goods and convenience services). It may also tighten labor markets and force employers to use more capital-intensive production systems.

• *The average age of the population and the workforce will rise, and the pool of young workers entering the labor market will shrink:* As the baby boom ages, and the baby bust enters the workforce, the average age of the workforce will climb from 36 today to 39 by the year 2000. The number of young workers age 16–24 will drop by almost 2 million, or 8 percent. This decline in young people in the labor force will have both positive and negative impacts. On the one hand, the older workforce will be more experienced, stable, and reliable. The reverse side of this stability will be a lower level of adaptability. Older workers, for example, are less likely to move, to change occupations, or to undertake retraining than younger

ones. Companies that have grown by adding large numbers of flexible, lower-paid young workers will find such workers in short supply in the 1990s.

- *More women will enter the workforce:* Almost two-thirds of the new entrants into the workforce between now and the year 2000 will be women, and 61 percent of all women of working age are expected to have jobs by the year 2000. Women will still be concentrated in jobs that pay less than men's jobs, but they will be rapidly entering many higher-paying professional and technical fields. In response to the continued feminization of work, the convenience industries will boom, with "instant" products and "delivered-to-the-door" service becoming common throughout the economy. Demands for day care and for more time off from work for pregnancy leave and child-rearing duties will certainly increase, as will interest in part-time, flexible, and stay-at-home jobs.
- *Minorities will be a larger share of new entrants into the labor force:* Non-whites will make up 29 percent of the new entrants into the labor force between now and the year 2000, twice their current share of the workforce. Although this large share of a more slowly growing workforce might be expected to improve the opportunities for these workers, the concentration of blacks in declining central cities and slowly growing occupations makes this sanguine outlook doubtful.
- *Immigrants will represent the largest share of the increase in the population and the workforce since the first World War:* Even with the new immigration law, approximately 600,000 legal and illegal immigrants are projected to enter the United States annually throughout the balance of the century. Two-thirds or more of immigrants of working age are likely to join the labor force. In the South and West where these workers are concentrated, they are likely to reshape local economies dramatically, promoting faster economic growth and labor surpluses.

In combination, these demographic changes will mean that the new workers entering the workforce between now and the year 2000 will be much different from those who people it today. Non-whites, women, and immigrants will make up more than five-sixths of the net additions to the workforce between now and the year 2000, though they make up only about half of it today:

	1985 Labor Force	Net New Workers, 1985–2000
Total	115,461,000	25,000,000
Native White Men	47%	15%
Native White Women	36%	42%
Native Non-white Men	5%	7%
Native Non-white Women	5%	13%
Immigrant Men	4%	13%
Immigrant Women	3%	9%

Source: Hudson Institute.

Juxtaposed with these changes in the composition of the workforce will be rapid changes in the nature of the job market. The fastest-growing jobs will be in professional, technical, and sales fields requiring the highest education and skill levels. Of the fastest-growing job categories, all but one, service occupations, require more than the median level of education for all jobs. Of those growing more slowly than average, not one requires more than the median education.

Ranking jobs according to skills, rather than education, illustrates the rising requirements even more dramatically. When jobs are given numerical ratings according to the math, language, and reasoning skills they require, only twenty-seven percent of all new jobs fall into the lowest two skill categories, while 40 percent of current jobs require these limited skills. By contrast, 41 percent of new jobs are in the three highest skill groups, compared to only 24 percent of current jobs (see Figure 1).The changes ahead in the job market will affect different groups in the society in different ways. While young whites may find their jobs prospects improving, for black men and Hispanics the job market will be particularly difficult (see Figure 2). In contrast to their rising share of the new entrants into the labor force, black men will hold a declining fraction of all jobs if they simply retain existing shares of various occupations. Black women, on the other hand, will hold a rising fraction of all jobs, but this increase will be less than needed to offset their growing share of the workforce.

Six Policy Challenges

These trends in the emerging economy suggest six policy issues that deserve the greatest attention:

Stimulating World Growth: For more than a decade, American policymakers have been concerned with the U.S. balance of trade, the nation's deteriorating ability to compete with other nations, and the

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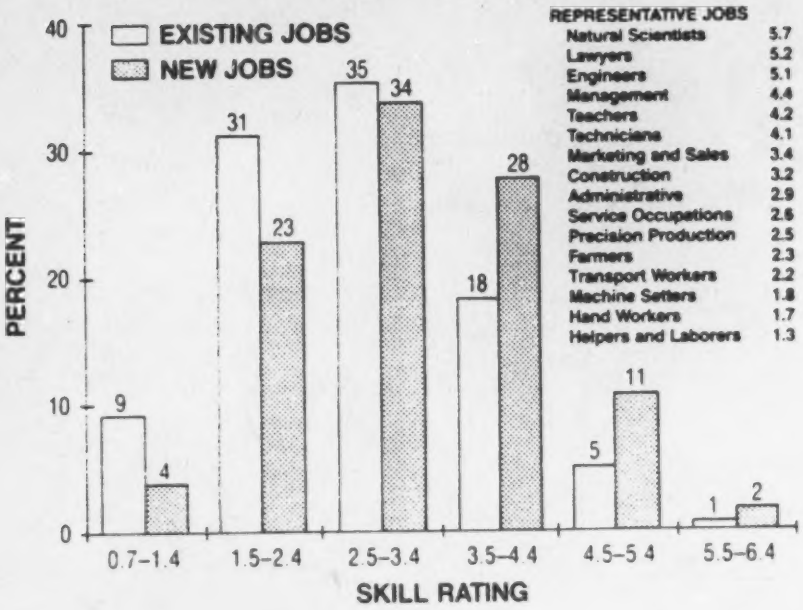
Figure 1
LOW SKILLED JOBS ARE DECLINING



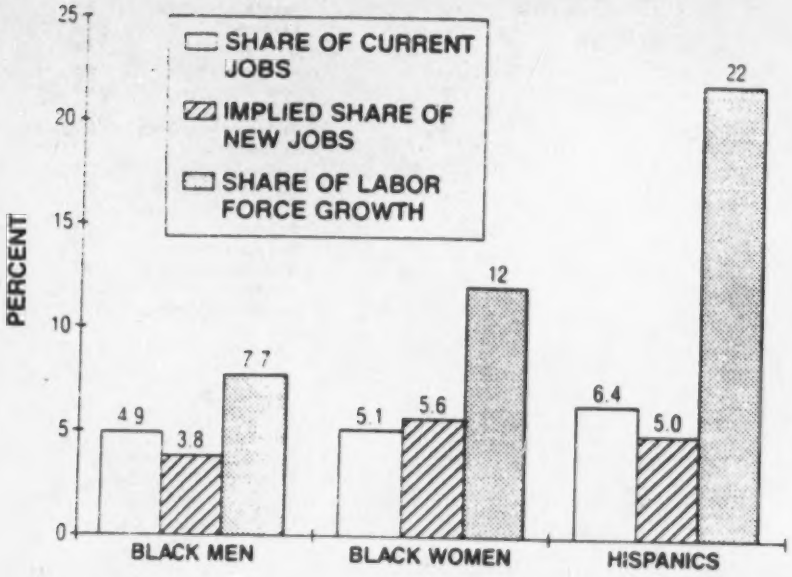
Source: Hudson Institute.

presumed unfairness of the trading policies of other countries. These issues, while important, are not the most critical international concerns facing the nation. U.S. prosperity between now and the end of the century will depend primarily on how fast the world economy grows and on how rapidly domestic productivity increases. It will depend very little on how open or closed the Japanese market is to American goods, or even on how soon U.S. trade accounts return to balance.

In particular, it is important for the United States, along with other industrial countries, to find ways to restimulate growth in the developing world. These nations that are still on the threshold of industrialization have the greatest opportunities for rapid growth that can stimulate the world and U.S. economies.

At the same time, efforts to improve U.S. competitiveness must always be undertaken within the context of strengthening the world economy. The envy and anger that many in the United States feel toward Japan's success should not blind policymakers to the reality

Figure 2
BLACK MEN AND HISPANICS FACE THE GREATEST DIFFICULTIES IN THE EMERGING JOB MARKET



that as Japan (and every other nation of the world) grows richer, the United States will benefit. Just as it is easier for a company to prosper in a rapidly-growing market than to capture market share in a shrinking one, so it will be easier for the United States to prosper in rapidly-growing world markets than in static or shrinking ones.

Of course, the U.S. *share* of world growth is also important. But most of the steps that must be taken taken to improve U S. competitiveness have little to do with changing the behavior of the Japanese or the Koreans. Instead, they involve changes in the propensity of Americans to borrow and spend rather than to save, major improvements in the educational preparation of large numbers of prospective workers, and reforms in the practices and laws that encourage America's best and brightest to provide legal advice in corporate takeovers rather than to build companies that exploit new technologies.

Improving Productivity in Service Industries: Manufacturing still controls the imagination, the statistics, and the policies of the nation, even though it now represents a small and shrinking fraction of

national employment and output. The nation's mental image of progress continues to be one in which manufacturing plants produce more cars, computers, and carpets per hour. But services are a far larger segment of the economy and the sector whose productivity has actually declined in recent years. These industries—health, education, trade, finance, insurance, real estate, and government—must be the targets of government efforts to improve productivity.

To realize this objective, new efforts must be made to tear down the barriers to competition in many of the service industries where competition does not now exist. At the same time, new investments must be made in research and development targeted toward improving service industry productivity.

In education, for example, competition is needed at the elementary and secondary school level, where the monopoly position of the public schools has stifled innovation. In order to provide a benchmark for measuring gains, national standards and nationally comparable tests are essential. At the same time, new investments are needed in educational technology, in particular to develop a large base of public domain software to teach math, reading, science, and more advanced courses.

In health care, the steps taken to inject competition into the system must be extended, while new investments are made in productivity-enhancing technologies such as automated diagnostics. In a range of other government services, privatization and competition promise to provide great productivity gains.

Improving the Dynamism of an Aging Workforce: At the same time that the workforce is aging and becoming less willing to relocate, retrain, or change occupations, the economy is demanding more flexibility and dynamism. Despite general recognition of the importance of a flexible workforce, many national policies fail to promote this end.

For example, the nation's pension system is one in which most retirement benefits are tied to the job. In many cases, employees receive no benefits if they leave after a few years, and, by the time they reach mid-career, they would suffer major benefit losses if they switched employers. The current system tends to inhibit workers from changing jobs and to discourage companies from hiring older workers.

Similarly, the unemployment insurance system has been largely used to provide income support to workers who are laid off. Rela-

tively little has been done to make the system one that promotes relocation, retraining, and job search.

Although worker retraining has become a catchphrase, and the federal government and private industry now spend billions of dollars for retraining, there is still no national consensus that all workers should expect to learn new skills over the course of their worklives. Except in a few companies, training is confined mostly to the top and bottom ranks of employees, with little systematic effort to insure that all workers are constantly reinvesting in themselves to avoid obsolescence. National policies that promote such corporate and individual attitudes toward retraining should be backed up with changes in the tax code to encourage lifelong education.

Finally, the goal of promoting dynamism requires reconsideration of national policies on immigration. The most careful studies of legal immigrants have concluded that they are a valuable asset to the nation and help to stimulate economic growth and change. The need for more, better-educated immigrants to help staff a growing economy will increase as the growth of the population and labor force slows in the 1990s. Despite the political and social objections, the nation should begin a program of gradually increasing its quotas and opening its doors to more individuals desiring to enter the country.

Reconciling the Demands of Women, Work, and Families: America has become a society in which everyone is expected to work—including women with young children. But many of society's institutions were designed during an era of male breadwinners and female homemakers.

What is needed is a thoroughgoing reform of the institutions and policies that govern the workplace, to insure that women can participate fully in the economy, and that men and women have the time and resources needed to invest in their children. For example, some formula is needed to provide parents with more time away from work. Flexible hours, the use of sick leave to care for children, more part-time work, pregnancy leaves for mothers and fathers, and other innovations are expensive, but ultimately necessary changes in the structure of work that will accommodate the combination of work and family life. Similarly, the need for high-quality day care has not yet been fully addressed. Government and private mechanisms to provide for the care of the children of working parents need further development.

14

The increase in the numbers of working women also has implications for the current debate over welfare reform. The current stay-at-home welfare program was designed long before most women worked. Now that a majority of nonwelfare women with young children work, it no longer seems cruel to require welfare mothers to do so. The current system should be replaced with one that mandates work for all able-bodied mothers (except for those caring for infants), while providing training, day care, and job counseling.

Integrating Blacks and Hispanics Fully into the Workforce: For minority workers, the changes in the nation's demography and economy during the 1990s represent both a great risk and a great opportunity. With fewer new young workers entering the workforce, employers will be hungry for qualified people and more willing to offer jobs and training to those they have traditionally ignored. At the same time, however, the types of jobs being created by the economy will demand much higher levels of skill than the jobs that exist today. Minority workers are not only less likely to have had satisfactory schooling and on-the-job training, they may have language, attitude, and cultural problems that prevent them from taking advantage of the jobs that will exist.

If the policies and employment patterns of the present continue, it is likely that the demographic opportunity of the 1990s will be missed and that by the year 2000 the problems of minority unemployment, crime, and dependency will be worse than they are today. Without substantial adjustments, blacks and Hispanics will have a smaller fraction of the jobs of the year 2000 than they have today, while their share of those seeking work will have risen.

Each year of delay in seriously and successfully attacking this problem makes it more difficult. Not only will the jobs become more sophisticated and demanding, but the numbers of new workers entering the workforce will begin to increase after 1993. Now is the time to begin investing in education, training, and other assistance. These investments will be needed, not only to insure that employers have a qualified workforce in the years after 2000, but to finally deliver the equality of opportunity that has been America's great unfulfilled promise.

Improving Workers' Education and Skills: As the economies of developed nations move further into the post-industrial era, human capital plays an ever-more-important role in their progress. As the

society becomes more complex, the amount of education and knowledge needed to make a productive contribution to the economy becomes greater. A century ago, a high school education was thought to be superfluous for factory workers and a college degree was the mark of an academic or a lawyer. Between now and the year 2000, for the first time in history, a majority of all new jobs will require postsecondary education.

Education and training are the primary systems by which the human capital of a nation is preserved and increased. The speed and efficiency with which these education systems transmit knowledge governs the rate at which human capital can be developed. Even more than such closely-watched indicators as the rate of investment in plant and equipment, human capital formation plays a direct role in how fast the economy can grow.

If the economy is to grow rapidly and American companies are to reassert their world leadership, the educational standards that have been established in the nation's schools must be raised dramatically. Put simply, students must go to school longer, study more, and pass more difficult tests covering more advanced subject matter. There is no excuse for vocational programs that "warehouse" students who perform poorly in academic subjects or for diplomas that register nothing more than years of school attendance. From an economic standpoint, higher standards in the schools are the equivalent of competitiveness internationally.

Promoting world growth, boosting service industry productivity, stimulating a more flexible workforce, providing for the needs of working families with children, bringing minority workers into the workforce, and raising educational standards are not the only items on the nation's agenda between now and the year 2000. But they are certainly among the most important.

More critically, they are issues that will not go away by themselves. If nothing unusual is done to focus national attention and action on these challenges, they are likely to be still unresolved at the beginning of the next century. By addressing them now, the nation's decisionmakers can help to assure that the economy and the workforce fulfil their potential to make the year 2000 the beginning of the next American century.

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The CHAIRMAN. I want to thank you very much, Dr. Packer. You did an excellent job, maybe because a lot of your thoughts parallel my own, but that is probably the greatest compliment I could give you. When you get to be 60 years old, you can say that without blushing, you know.

Let me make a couple of observations and ask a couple of points. I think your testimony is excellent, because it seems to be basically axiomatic to me that if we have a given pot of resources, which we have, in the budget battle that is about to ensue or that is already under way, and in fair play to all our colleagues, having nothing to do with the elephant or the donkey, it is a genuine interest as to where we should put our resources, and then everybody starts to concentrate on quote-unquote priorities, and it seems to me that if you short all of the areas of the breadth and scope of the Government that you are responsible for, you have done everybody in at that point.

So it seems to me that what we are talking about: Where will this new wealth be created when we are expending our resources, particularly in the area you mentioned of, demographically, the relationship to those between 75 and 85 years old, and you go into the billions? People do not realize that.

And if you look down the future and you look at the aging population, as you well expressed, it seems to me that more and more of those resources are going to have to obviously go in that direction, which are nonproductive. Don't misunderstand me. They are nonproductive in the sense that they do not create new wealth. They are an expenditure we are making for the quality of life in America, and that is a given fact that is there.

I am not talking about the employee or the worker in the group who is helping those people as the assistant to the nurse, the case that you point out, I am just talking about the overall dynamics and economics involved, which is leading to part of the tragedy to this country—people sleeping on grates and the whole bit.

So it seems to me to be axiomatic. If you are going to put more money into housing, into the homeless, into those that do not have jobs, and the mentally ill, and so on, you are going to have to take it out of that category, and it is nonproductive, it is capital we have to use for the quality of life of people.

Is that a fair comment to make basically?

Dr. PACKER. Yes, it is the case that in some sense the R&D budget should not be offset against its own other spending, but what do you spend for health?

The CHAIRMAN. Well, that is okay, but that is an expenditure we are going to make.

Now what we have to get across to our brothers and sisters, particularly coming from this committee, is that where science, space, technology, and education are involved, that is the creative force of the new wealth, that is the theme we are trying to concentrate on, and if we can understand that from this committee level's point of view, then we can start to say to Congress, "As you make these investments, do not make a political investment because you are going to get more votes, because you are going to put more housing in this city or that city; that is not going to solve the problem; that is going to be a disservice to the American people. What you have

to start looking at is the broad-based areas as to where we put the research to achieve specific goals."

Dr. PACKER. Exactly.

The CHAIRMAN. The previous witness made the point of the high-resolution television we talked about, and there is only one company left in the country that produces television at all. What is it? Sylvania, as I understand it. There is a $4.5 billion contract to go out by FAA, of which $1 billion is going to be allocated to Sony, because they are more advanced than we are. We let that happen, and I think we could still do something about it if we got into the issue, if you understand where I am coming from.

Therefore, in this Member's judgment—and I am looking at the three issues when you speak of research, specifically in the educational field, and which we will get into in depth, by the way. It seems to me that there is a series of things we have to do not only in allocating existing resources, we have to make decisions—what would you say?—human decisions.

For example, what is the purpose of having a senior, a person who retires at 62 or 65, who is prohibited from working between 65 and 70, because if they do, you are going to take away their resources? Now, to me, that is a stupid law, and, being a member of this body, I can say that, and there is no answer to that whatsoever, because where we have the shortage of people we are talking about, those very same seniors come to me in my district by the thousands and say, "What are you doing this to us for? We want to go to work, and we do not want to lose our pension rights," and so forth and so on.

All I am simply trying to say is—I suppose it is not a question, it is more of a statement—I see a series of things like that, that are hidden away and exist in our whole budget structure, that are actually working enormously toward the lack of productivity or reducing the productivity of the country. Would you say that is a fair observation?

Dr. PACKER. Yes, I would.

The CHAIRMAN. Okay. Well, why do not you and I just vote and the whole issue will be over?

Dr. PACKER. The ayes have it.

The CHAIRMAN. The chair recognizes the distinguished gentleman from New York, Mr. Boehlert.

Mr. BOEHLERT. Dr. Packer, if you were giving a grade to public education in America, K through 12, how would you grade what we are doing?

Dr. PACKER. Oh, a C perhaps. I mean it is struggling along. I think Al Shanker had a piece in the Times this week about the high school in most of our minds, about what it looked like when we went. It is very much like the high school that exists today, and it has just not changed.

Mr. BOEHLERT. It concerns me when I read reports, for example, that when high school seniors in the United States are compared with our counterparts in other nations around the world, we come out twelfth or thirteenth in math and science, not only behind Japan and West Germany and Great Britain, our principal competitors, but also behind Singapore, Hong Kong, and that is a scary and alarming figure.

Dr. PACKER. I'll give you a worse example. I was out in a major, major school system, which I won't mention, and I said, "If I could increase the productivity in that school system and put through four classes a year instead of three classes a year, would you really be eager to get that?" and they said, "No, no, no. The way we get compensated, we get paid per day anyway, and we'd only use up more paper. So you have a 33 percent improvement in productivity available to us. that is more—just a headache. We're not interested."

Mr. BOEHLERT. So you would argue strongly then in favor of major changes in K through 12 public education.

Dr. PACKER. We spend 95 percent or so—or so of education spending goes for staff as opposed to R&D, technology, all the other things. If you went to a hospital that used the technology of 80 years ago, you would not think you were being treated properly, and if you would go to a school that has the same technology as 80 years ago, you'd go to most schools. It is just not looked at properly—the same curriculum, the same methodologies. Where else in our economy can you see something that hasn't changed?

Mr. BOEHLERT. They are probably using the same lesson plans.

Dr. PACKER. The same lesson plans, the same blackboard, same chalk, same teacher up in front of 30 students saying, "Hold the paper over here," and do that sort of thing.

Mr. BOEHLERT. Well, we are determined on this committee to bring about some change, and, as the chairman has indicated, and as my subcommittee chairman, Mr. Walgren, has stated many times in the past, we have got to do something a lot better, and there is no way that I know to solve the problem without putting more money into it. I mean all the best intentions in the world aren't going to do it by themselves. You have got to have more money. So you have to be encouraged that we are going to be the education Congress.

Let me ask you a question. You mentioned the alarming number of figures of people in the 21 to 25 age bracket who require upgrading in their skills in order to be productive in the work force. Is it time that we changed our thinking in terms of what the Government guarantees in terms of education? Should we have something more for—go beyond the traditional, we educate the child or provide the resources to educate the child, up to age 16, and then we sort of walk away from it, our responsibility is fulfilled? Should we have some sort of voucher system that we develop that would guarantee a couple of years of retraining in whatever skill area might be necessary, and later in life? Is that something that you find appealing?

Dr. PACKER. Well, I am not sure it is the voucher system, but if—

Mr. BOEHLERT. Well, it does not have to be a voucher.

Dr. PACKER. You go to a community college in a State like California. If you are in an academic track, that community college will receive $3,500 to $4,000 for the student. If you are a Hispanic dropout and coming back to school, and that community college may have a program for you, it receives $1,500. The ratio is just out of sight.

I, frankly, am not sure it needs as much new money as it needs new thinking. It most likely is going to need some new money to

bribe people to do new thinking, but it is more money for the same—more money for what they are doing today is not a recommendation I would make. You know, we are talking about loans to Latin America that will give loan forgiveness if they will change the way they behave economically. that is the way I would go to the education system—no more money for the way you are doing it today.

Mr. BOEHLERT. Then you must find attractive the President's proposal to reward— to give incentive grants to educational institutions that perform.

Dr. PACKER. That makes sense, but I really would like to bring you back to the R&D issue. We need some R&D about how to teach, how to teach with computers, how to teach with video. I mean it can not just be blackboards and chalk.

Mr. BOEHLERT. I know the whole economy is changing with less emphasis on the manufacturing sector and more on the service sector. That is the reality of the future, the present, too.

But you indicated that I think it was 2.6 increase—2.6 percent increase in productivity in the manufacturing sector. While that is good, it is not particularly exciting. Wouldn't you argue for more funding for such things as robotics?

Dr. PACKER. I am not so sure. I think those things that are in business's interest business ought to do something about, but business pays—I mean General Motors pays more for health care than it does for steel, and if I were General Motors, I would say, "Hey, I want that bill reduced." I mean I have that situation in education, where we go to business and say, "Well, how about some money for retraining workers, or training workers?" and some of them are nasty enough to say, "You know, we think we've paid for that once in paying property taxes for education, and we are somehow wondering why we have to pay a second time." I think David Cairns has been eloquent on that subject.

Mr. BOEHLERT. Well, that is part of the problem with corporate America, though. Corporate America, in my estimation—and with all due apologies to the Chamber of Commerce and the National Association of Manufacturers, corporate America will write a check and say they have contributed to a solution of the problem. If you look at school boards across America, where is corporate America represented? Where is the academic community represented? Who runs for the school board? Well, that is another story for another day. But you know the point I am making.

Somehow we have all got to get involved in this, but, unfortunately, too many people point here or to our State capitals, and, I maintain, show me a society that depends on government to succeed and I will show you a society destined to fail. I mean we have all got to be involved, and corporate America has got a long way to go to earn higher marks from me.

Dr. PACKER. I think that is true, but I think the education system has a long way to go to invite true partnership with business. I think most partnership with business has been, you give the money to the schools and the schools do what they want, and that is not a partnership, that is the kind of relationship I have had in the past with my children.

Mr. BOEHLERT. Well, it will be interesting to see how the—that sounds familiar—it will be interesting to see how the educational community responds to the President's initiative in alternative certification. I mean Albert Einstein could not teach in our public schools today.

Well, thank you, Dr. Packer.

Thank you, Mr. Chairman.

The CHAIRMAN. I thank the gentleman.

Further questions?

The gentleman from New Mexico, Mr. Schiff.

Mr. SCHIFF. Dr. Parker, since I do not personally have a scientific background, it is a pleasure to have a witness here I think I understand in this committee.

Dr. PACKER. Thank you.

Mr. SCHIFF. I have a couple of questions. One: You referred to a reduction in annual productivity in the United States. In 25 words or less, can you explain, how do we measure productivity? How do we come to the conclusion of 2 percent per year from 1948 to 1973 and .7 percent and so forth more recently?

Dr. PACKER. Well, at the overall and simplest level, you just take the GNP and you divide it by the number of hours worked. So it is the Gross National Product corrected for inflation, divided over the amount of hours of work we put in. In real terms that you can understand, if a hotel can handle twice as many people because it is using a computer-based reservation system, the productivity has gone up: more output for less people.

I think there was a piece in the Post or the Times on Sunday about self-service retail stores. That will show up as increased productivity because fewer workers are turning over more dollars worth of goods in a retail store.

Mr. SCHIFF. In your opinion, why has productivity declined from what you call the golden years to more present times?

Dr. PACKER. Well, I think there are only two reasons left. One is that the pace of innovation has diminished, and the other, which is the one I have concentrated on, is, I think the school system has not recognized that the world has changed and that the population has changed, that there are women going into science, that there are blacks and Hispanics going into business. I mean this is a school system that still acts as if we have to have the summers off so we can bring in the crops when 3 percent of the people are in farming.

Mr. SCHIFF. I miss your point, though. I understood your point about we are educating a majority of minorities; I understood what you mean. But in what way is the educational system, in your judgment, not addressing minorities? In other words, aren't students students as they go through the system, regardless of whether they are white males or whether they are Hispanic females?

Dr. PACKER. Not when they are among students who come from a society that didn't have a written language, not when they are Spanish speakers who can not speak English, and that is just the beginning. I think we all have our strengths and weaknesses, and the way we have it now, you learn our way, and if you learn a little differently, we do not have anything for you.

I think the research has indicated that we have different ways of learning, and we have to tailor the ways of teaching to the way people learn, and we do not. This is it; you take it or leave it.

Mr. SCHIFF. Is your point that you believe that groups by cultural backgrounds learn differently and therefore educational programs designed for Caucasians are not as effective for other groups?

Dr. PACKER. No, I do not mean that. We tend to teach in context, and when you teach about—math about lamb chops to people who have never eaten lamb chops, it somehow does not go over quite so well. I mean the examples that we use do not connect to lots of people, and it is tough if you do not speak English at home to come into a school where that problem is not addressed.

We are complicated things, us human beings, and I think that is one of the R&D efforts, to see just how complicated we are and how different we are, and you can use technology to change the message to suit the fact that some of us find math easy and some of us think math is impossibly difficult. Some of us listen well, and some of us read well, and it could be different for different people, and so I think that is right.

I mean we have had many, many complaints from women that, you know, when it gets to courses about computers or math, they do not ask too many questions; they just push the women off to the side and let the young men have the math, and computer, and science courses. We act as if, you know, the women do not need it, they're going to go home and take care of the kids and make the formula, and the men will go to work. Well, that is not the reality any more, but the schools have taken their time getting around to finding out about that.

Mr. SCHIFF. Okay. Thank you, Mr. Chairman. Thank you, Dr. Packer.

The CHAIRMAN. Further questions?

The gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. First of all, Mr. Chairman, I want to congratulate you for holding these hearings, and this is just a bit of responsibility and far-thinking on your part, and especially this witness, who I think has done—I agree with you, has done an excellent job in displaying to us a national problem and a new perspective on the national problem.

First of all, I would like to ask Dr. Packer about the wealth of our people. We are talking about new wealth, the creation of new wealth, and the use of technology. Do you think that we have—by what you are saying, we have undervalued—we have misevaluated, I should say, the value of people themselves in the determining of a national wealth. Isn't that basically one of the points you are making?

Dr. PACKER. Yes, and I take my script from an old friend of mine, Jim Fowler, who has just written this book after his experience in Japan, and the first thing he and others have pointed to is that the Japanese have very little physical resources—they recognize that the resources are the humans that live there—and, secondly, that if you look at the Japanese, who have a higher IQ on average than Americans do, they have no more people over 130 IQ

than we do. All of the difference is in the bottom—so-called bottom half.

In the United States, it is appropriate to say, "I can not do math." In Japan, it is appropriate to say, "I can not do math in two hours a night, so I take three hours a night."

Mr. ROHRABACHER. So when we are talking about the value of our people in terms of national wealth, you would believe, and by your testimony, we are talking actually about using technology to add value to the people themselves as a source of production for new wealth in our society in the future. Isn't that right?

Dr. PACKER. Precisely. Precisely.

Mr. ROHRABACHER. This committee is involved, actually, in a major decision as to some directions we are going to go in terms of high-definition television, which you mentioned in passing, and in some ways it might be versus a technology which is based on digital electronics, which would actually be more interactive and provide a more interactive potential than just an entertainment factor or a work factor which high-definition television—could you, if you have some understanding of that particular issue—if you have something to say about that.

Dr. PACKER. I have done some work in interactive video.

Let me first say that if I were guessing about the biggest industry in the United States in the next century, it will be using technology to inform and teach. Now perhaps the Congress will continue to operate this way with witnesses, but lots of other people will be using technology to do this educational process. An investment banker who wants to find out about coal mining in Alabama will be able to use technology to find out about that in a day instead of in three days, and three-year-old kids will learn about math using technology.

So using education and information in the broadest sense, the use of hardware technology—computers, video, stuff like that—in my judgment, will be bigger than computers itself, bigger than oil and gas, bigger than automobiles, as the major industry.

Mr. ROHRABACHER. Now when you are talking about this technology in the teaching process, you are talking about interactive in the sense that we will have computer technology that will permit a back and forth between the learner and the machine itself, are you not? And that, which is totally different than just a new type of vision that is created by a high-definition television. Maybe you could explain that a little bit to us.

Dr. PACKER. Well, we brought some investment capitalists in yesterday to see a machine in town where we are teaching standard things like, how do you understand an invoice?

Mr. ROHRABACHER. Could you repeat that? How do you understand?

Dr. PACKER. Teach somebody who, let us say, has been a high school drop-out how to deal with an invoice and check a shipment, and so there is a voice, and there is the invoice on the screen, and the voice says, "How many wrenches did we get?" and you push the screen, and if you push the number next to the wrenches it beeps one way at you, and if you push the wrong place it boos at you, and there it is, quite interactive.

You have seen pictures on the TV of the things that are in the shipment, and one of the things you have not seen is screwdrivers, but on the invoice is screwdrivers. Then the voice says, "Did we get everything?" You say yes, and it says, "Oh, no, you didn't"—you know, you didn't get—so it is there today. I mean it is a technology that is there today, but that to me is much more important than high-resolution TV for entertainment purposes.

Mr. ROHRABACHER. So you would think that actually, through this use of interactive computer technology, digital technology, that we can add vast new wealth by adding value to our people in a mechanized fashion.

Dr. PACKER. Yes, yes, and I think it is a big export product, too. So you end up helping your balance of payments problem by selling that elsewhere.

Mr. ROHRABACHER. Okay. And part of the reason this—you know, when you talked about our education system not being mechanized, not using the technology—I guess I had better hurry up here—not using the technology that is available, would you say that this has a lot to do with the fact that we do not have a profit motive in most of America's education, that we are actually—it is a socialist enterprise basically?

Dr. PACKER. No. I just think it is because there is no concept of a capital budget in half of the Federally-funded programs. There is no capital budget in the Federal JTPA program. If your State gets JTPA monies and says, "I would like to put 10 percent aside for investment purposes," there's no way for you to put that down.

Mr. ROHRABACHER. Okay. One last question. Mentioning education and corporate America, is not today corporate America actually providing more training in terms of the money that they are putting into training and education of their own workers? Hasn't this gone up geometrically in the last two decades?

Dr. PACKER. Well, it is $30 billion, but most of it is to teach management and to teach marketing people. We have a highly mobile labor force, and there is a reluctance to teach people at the lower end basic skills.

Mr. ROHRABACHER. But in the future you would project that corporate America would be aiming at that lower end?

Dr. PACKER. I think so, but I think there is going to need to be some cooperation. Remember that most of the workers in this country do not work for big companies, they work for small companies, and more of the illiterates are in the small companies than in the big companies.

My suggestion is, the big company has got a stake in the literacy of their customers and their suppliers that far exceeds their stake of the literacy of their own people. You cannot sell high-tech products to a low-tech population. It is tough enough to operate the damned VCR.

Mr. ROHRABACHER. Thank you, Mr. Chairman, and thank you for coming, Dr. Packer.

The CHAIRMAN. The chair recognizes the gentleman from California, Mr. Packard.

Dr. PACKARD. Thank you, Mr. Chairman. I will be very brief.

Unfortunately, I was unable to hear all of your testimony. I have read almost all of it.

The drain from education, the best minds in education, to the private sector has been of concern for decades now. Do you see a reversal of that, and, if so, how is it going to come about, and how do we structure it so that we actually take advantage of the private sector in terms of our formal educational system?

Dr. PACKER. Well, let me make very concrete proposals. I would get together corporate leaders in various industries and sit down and decide what a curriculum needs to be and what people have to learn.

My old example is, everybody who has studied algebra has taken that problem where the train leaves Chicago at 10 o'clock in the morning and the other train leaves New York at 3 o'clock in the afternoon, and when do they cross? In my entire lifetime, I have never seen that problem in the real world.

The CHAIRMAN. that is because you do not ride Amtrak.

Mr. PACKARD. The answer is, they never cross.

Dr. PACKER. They never cross.

Mr. PACKARD. Well, you are right. Your wife never seems to leave New York at the same time you leave Chicago and then you cross somewhere.

Dr. PACKER. So I think you have got to sit down with [illegible]iness—let us say people who are running hospitals or health facilities—and say, "What is it that you have to know?" Maybe you have to know how to admit somebody, take a history, know that when somebody comes in with heart pains this guy has to be dealt with right away before you find out where their mother lives, and their Blue Cross number, and everything else.

Mr. PACKARD. So you do not see the corporate loaning their people to the educational system to teach the way that we have been taught in the past?

Dr. PACKER. Not the way we have been taught in the past, no.

Mr. PACKARD. They will become practical instructors but still in a formal sense, in the classroom sense.

Dr. PACKER. No. What I am saying is, we went to Kelly Services, and we said, "What do you need to know to be trained as a secretary?" They say. "Spelling is less important now because we have Spellcheck in the computer, but we need people who can proofread, who know when it should be T-H-E-I-R and T-H-E-R-E." Well, how long do you think it is going to take the school system in most districts to get up to that change in the technology in which proofreading is hardly ever dealt with but you have to remember these 100 words? And that is what I mean. Just bring in—if you want to train people for Kelly Services, tell us what you need to know, or for office, and make sure it is moving, it is a moving target, what are the real skills. How to write. Okay, let us go how to write. But, you know, not write a fiction story, because that does not come up, write a two-page memo to the chairman.

Mr. PACKARD. Do you sense that there will be a resistance from the formal education system and the educators of allowing the private sector to pull in or to come in and assist in the educational process?

Dr. PACKER. Not only do I sense there will be, I sense that there is.

Mr. PACKARD. How do we overcome that?

Dr. PACKER. Well, that is what you have got to spend the more money for, and, you know, school boards do respond to business communities, if the business community says, "Listen, we can not manage that way any more."

Mr. PACKARD. Do you think we can structure that legislatively?

Dr. PACKER. I think you can. I think you can assist legislatively. I think you can assist with political leadership. That does not always require legislation. With very modest money, very modest money, you could accomplish much of that.

Mr. PACKARD. I thank you very much.

The CHAIRMAN. The chair recognizes the gentleman from Connecticut, Mr. Shays.

Mr. SHAYS. Thank you.

I would like to join my colleague from California who thanked the chairman for this hearing. I have to tell you, it is one of the most interesting that I have attended, and, again, not to get a sense of pessimism, but I am kind of an impressionable person, and I find myself saying this, and I would love to know if it is accurate, that if we had the same productivity growth in the seventies and eighties that we had in the fifties and sixties we would have 25 percent more wealth collectively, and I think that is fairly true.

But what I think I hear you saying to me is, it is not just—I have had two reasons explained for that. I mean, one, basically, that as we increase our technology, it is harder to gain the same jump in growth; it becomes harder to squeeze out new productivity. But I have never had anyone quite explain it to me that we have become more service oriented, and the service industry is, by its nature, not all that efficient, and it is difficult, I think—and maybe I am making an assumption—to realize the same productivity growth in the service industry. Is that accurate?

Dr. PACKER. No. I think in the past the service sector productivity, while not quite as good as manufacturing, was pretty healthy. Now it may be something that goes as follows: Right after World War II, there were "mom and pop" stores, and then they were replaced with supermarkets, and the supermarkets were much more productive. That is, one clerk in a supermarket turned over considerably more goods than mom and pop. Now it took lots of investment, but it worked, and it is not easy to measure productivity by the way you are manufacturing any more.

The show that is going on now, the computer show, will have the new 486 chip which will become common in the personal computers, much, much faster—six times as fast in many ways as the old 286 chip. How to measure the productivity of the guy making the machine is a mystical question.

Mr. SHAYS. Well, we are all in the service industry as Congressmen. I have a situation where we provide—we get out so much mail a day, and I ask why we can not do more, and I am told in some cases, well, the way with more than 21 terminals and so on, our computer is working slower and so we can not input as quickly, and so on. Sometimes people come in the mornings so they can input and the computer works more quickly.

Now if there is an improvement in my computer system, is that an increase in the productivity of my service industry, or is that—

Dr. PACKER. If you are getting out more letters, yes. I mean you see productivity in the service industry go up exponentially.

Mr. SHAYS. That is my next question, though. It seems to me with computers and the ability we have to increase our productivity, why aren't we seeing the phenomenal growth in productivity in the service sector? I do not understand that.

Dr. PACKER. In some specific cases we are, but in general we are not, and part of the reason—maybe the most amazing case is the fax, which has replaced in many cases Federal Express which 15 years ago was a new idea, and now you have got a machine that moves it faster and cheaper by far with less people. So that business has gotten more productive.

Mr. SHAYS. I am not sure you are answering my question, though. I mean maybe I am not asking a question that could be answered, but it strikes me intuitively, you know, that there should be phenomenal growths in productivity because of the computer and what it has enabled me to do. We could not do half—we could not do a tenth of what we do now without the computer. Is it because we are just trying to do more? But if we are doing more, that is an increase in productivity, is not it?

Dr. PACKER. No. You are getting increases in productivity in parts of the service sector, but the other large parts, like the health care sector, is not showing that improvement.

Mr. SHAYS. We are told by OMB that Medicare costs, which in new dollars is $13 billion new dollars, which we want to hold at eight and some say it is a $5 billion cut and some say it is a $5 billion increase, but, whatever, we are saying in the year 2005 Medicare is going to equal Social Security. They are telling us in 2015 Medicare is going to equal Social Security and defense combined.

Now this is why I get a little pessimistic, because I frankly—and let me just ask one question after this—do not understand, without making some monumental social decisions, how we will increase productivity in the health care.

Let me say this to you. In all the areas that I have gotten involved in, I will have an expert who will tell me how we can save money in the health care, how we can be more productive—I mean, excuse me, in everything but the health care, but when it comes to health care, nobody has an answer.

Dr. PACKER. Well, I am not an expert on health care, but people have suggested, for example, that it would be healthy for patients to do more of the work for themselves that is now being done by nurses. That is one way to get more productive. Another way is to increase the proficiency of less expensive people, like nurses' assistants, and have them do jobs that nurses themselves do not want to do. That does not reduce measured productivity, because the hours are the same, but it does reduce costs. One does not have to spend too much time in a hospital to see that most people in a hospital are standing around doing nothing.

Mr. SHAYS. Just one other area very quickly. It strikes me that we can invest in two areas. One, we can invest in physical capital, and another is in the human capital, and is it your testimony to us that, basically, we are simply not investing enough in the human capital?

Dr. PACKER. That is right. Now some of that is physical things, like new interactive TV, but we no longer are in the widget-making business, we are in the service providing business, and the R&D needs to be to enhance services like health, but put it into human capital.

I mean one of the ways to save a lot of money in the health sector is to have fewer people sick. Now that sounds obvious, but lots of people end up in those places because they are uninformed or they are not encouraged enough to avoid certain diseases, and you do see a drop-off in heart conditions because people smoke less and do other things. That is a way.

Mr. SHAYS. I found your comments about education in terms of making it more relevant helpful, because it tells me how I can make a difference. But it is not as helpful in this other respect that when you say—and you have the advantage of saying something that I would be less comfortable saying. You could say, "Well, you know, we are not a farming nation any more; it is 3 percent; why do we have the summers off?" I can not contemplate what it would be like to tell my daughter that she would have to go to school in the summer, much less my wife, who teaches, and I guess what I am—that is why I get a little pessimistic, because maybe you are saying that has to happen, but, honestly, I do not see it happening.

Dr. PACKER. Maybe she wants three months off, and maybe if it is not the summer, she could take off the spring, so you could still have her take off three months, but you could have the school operate four quarters a year.

Mr. SHAYS. I am willing to make a lot of difficult decisions; I am not sure I am prepared to make that one.

The CHAIRMAN. I thank the gentleman from Connecticut.

Any further questions of this witness?

If not, Dr. Packer, I want to thank you very much. You have been very productive, and we appreciate it.

Dr. PACKER. Thank you.

The CHAIRMAN. Our next witness is Professor Rustum Roy, of the Pennsylvania State University.

Again, thank you. Your statement will appear in full in the record, and, Dr. Roy, if you would be kind enough to go ahead from there.

[The biographical sketch of Dr. Roy follows:]

RUSTUM ROY

Vita

Rustum Roy is Evan Pugh Professor of the Solid State and Professor of Geochemistry at The Pennsylvania State University. He also serves as Director of the Science, Technology and Society Program of the University.

Professor Roy is a materials scientist specializing in the design, synthesis and preparation of new materials. He is the author of some 500 papers and several books. His major research contributions include the invention of the sol-gel route to making ceramics, the development of the hydrothermal method and its application to oxide systems, the synthesis of new magnetic and ultralow expansion ceramics, and radioactive waste solidification. His work has been recognized by various awards from the Ceramic, Mineralogical, and Chemical Societies and by his election to the U.S. National Academy of Engineering, and as a foreign member of the Royal Swedish Academy of Engineering Sciences and the Indian National Science Academy and a honorary doctorate from the Tokyo Institute of Technology.

Professor Roy has been deeply involved in professional and educational innovation. He has been a major figure in the creation of the national field of interdisciplinary materials research by organizing national meetings and analyses of the field, and by being the principal architect of the Materials Research Society and the Materials Education Council. At the University, besides being the founding Director of the University's interdisciplinary Materials Research Laboratory for a quarter century, he played a major role in establishing geochemistry, and later solid state science, as academic disciplines on the campus. Most recently he has played the same role in creating and directing the Science, Technology and Society Program which covers the widest spectrum of disciplines. His innovations in the creation and delivery of new educational teaching materials have international significance for both the materials science and STS fields. Besides his materials research in molecular engineering of ceramics his current efforts are focused increasingly on the technological literacy of the general population via the STS route.

Professor Roy has been involved in science policy matters for two decades. He served three terms as a member of the Pennsylvania Governor's Science Advisory Commitee. At the Federal level he has served on many Boards, Committees and panels of the NAS-NRC-NAE, the Department of Defense and the National Science Foundation. He has been a consultant to some industries continuously for over twenty-five years and is a long-time advocate and practitioner of university-industry coupling. He has written widely and critically through books and papers on national science policy.

He has studied and written widely on matters of ethics and values as they are affected by science and technology. He was first chair of the National Council of Churches' Committee on Science, Technology and the Church, and in 1979 he was selected to give the prestigious Hibbert Lectures (in its Centenary year) in London, England, on the relationship of science and technology to contemporary religious insight.

6/87

STATEMENT OF DR. RUSTUM ROY, DIRECTOR, SCIENCE, TECHNOLOGY AND SOCIETY PROGRAM, PENNSYLVANIA STATE UNIVERSITY, UNIVERSITY PARK, PENNSYLVANIA

Dr. ROY. Thank you, Mr. Chairman.

Maybe I am bringing coals to Newcastle, because this is such an enlightened committee, but I thought I would start with that reference to Admiral Yamamoto in which he said, at the beginning of Pearl Harbor, that, "Today, we will awaken the sleeping giant, and we will rue the day when Japan awoke the sleeping giant."

My problem is that there is not any Pearl Harbor. So my first thought is to try to make the committee aware of what I perceive as the real situation with respect to the Japanese machine. It is not to make war but to make products, and in that I think the problem I have is that most people want to look on the bright side. I think the gentleman left, who was pessimistic, from Connecticut, but I am on that side.

The fact is that those of us who go to Japan regularly go inside the industrial machine on a six monthly basis and see our colleagues over there. We sound like Cassandras, and you know the fate of Cassandra. Even her father did not believe her. But the problem with that is, she may be unpopular, but she was right, and the Trojan horse destroyed Troy.

So I believe that the first thing to say is that the Japanese are very substantially ahead in the machine that makes what you have called, Mr. Chairman, science-based technology. They are so far ahead that we can hardly see them with a decent telescope.

So the first point is that they are really ahead, and we have got to accept it. In other words, we are not going to get a Pearl Harbor to tell us that they are good, we have got to try to come to terms with that. It is a machine that utilizes science, not creates it. There is a difference. They are a science eating machine not a science producing machine.

Now we have turned out a fairly decent science making machine. Even with that, we are slipping a little bit. But that is not the problem. Making science has little to do with using it. In fact, the people who make science frequently do not use it at all, and so we have—let me also say this is not my view as some kind of idiosyncratic view. I refer you to all the industrial personnel from my companies—Mr. AT&T, IBM—who go to Japan and see that machine. They all agree with this. I would not take the word of witnesses who have never been inside Japan's industry. It looks much different from out here.

Well, you made an allusion—I want to talk about the policy implications of what I see. The first one, Mr. Chairman, you referred to the buy-out issue. Let me say that the non-R&D sector is much more important. The buy-out mentality is killing this country, and there is no question about that.That is not my business today, but, in fact, those non-R&D issues are just as important. The cost of capital and the buy-out business are very important, but you did refer to them. I am commenting on that on the side.

But to turn to R&D policy, the Japanese R&D policy-makers, whom I study, put technology policy first and say science is derivative from technology. We, for 40 years—and I am in the academic

community for that long, 43 years at Penn State—we have been fooling you guys. We have been telling you that science leads to technology. That is balderdash. Mr. Keyworth used to come in here and testify to that effect, and that is balderdash. If you think that science leads to technology, please turn to that little figure in my testimony from the congressional Research Service which shows the increase of GDP versus the number of Nobel Prizes. Well, how come the Japanese have only won four Nobel Prizes and lead the world, and we have 150 Nobel Prizes and with 50 cents you get a cup of coffee? So what good does that do us?

It is not true what we have claimed, that science leads, by itself. That is what Mr. Vannevar Bush said. Alone, science is nothing. But science, put in the machine that makes technology a good industrial machine, is what your hearings are about. What our problem is, we do not have that machine any more.

If you do not have the machine, what do you do? Well, that cartoon tells you something about it in the testimony. They are a team playing group. They focus on the target, what is the goal, and they bring the team to bear. We are an idea-based machine which would say, "Hey, I've got a good idea. Maybe I'll win a Nobel Prize or get in the Academy," and that is what drives our system. Until we learn teamwork, until we learn focusing on the industrial target, the output, the national orientation of the university research groups, of many industrial research groups, is simply not going to help the Nation.

Now I use a football analogy. I come from a football school. We are a research university, but Penn State is a football school, and if Joe Paterno had a damn bunch of good quarterbacks and no receivers and no blockers, it does not do him any good to add more quarterbacks. Quarterbacks are good science; they throw the ball. But guess what is happening? The other team is picking it up and running in the other direction. So we have a lot of all kinds of receptions and turnovers.

I think that adding a fourth quarterback to his string would not help the productivity of the Nation, and, unfortunately, asking for more science to fix the technology problem is not the way to do it. You can not fix your problem of receivers by adding more quarterbacks. Now what does it mean?

So, of the two types of science, I think there is science relevant to human society, and there is science which is irrelevant to human society or not visibly relevant. I do not suggest that we get rid of science which is irrelevant, that is the cream of our culture, but at this moment in our history if we do not put our priorities on science relevant to our economy, to our technology, to health care, we are crazy. that is all I can say. So I suggest that we move in certain directions.

With respect to the industrial sector, somebody talked about consortia. I have studied the Japanese system. The Japanese system never puts money into a company to do research. The Japanese system matches industry which has already wanted, got together, and wants to go ahead. It supports them. It synergizes. The government synergizes. We kidded ourselves for 20 years saying, "Oh, the Japanese government is making Japanese industry." It was not. It is the Japanese industry which invests in long-range R&D. It is

cost of capital and all those things. For whatever reason, they are investing in R&D. The government synergizes with that, gives them long-term support. No Japanese thing is funded for one year—I mean the NSF nonsense, one- and three-year contracts. Everything is five- and seven-year modules. The Germans are now funding 10-year contracts. It does not cost any more money, it just means change the way we do business.

We tend to have overcommitted to certain kinds of research and undercommitted to others. So I am going to summarize which ones we should do. First is the tax reward system. I leave you gentlemen to do it. We must change the rewards on short-term and long-term capital gains. If we encourage people to just make money out of money, we get the system we have. The buy-out mentality—I think Senator Kennedy tried this about seven or eight years ago—we should do something about buy-outs. I leave those two.

I come to your favorite topic, Mr. Chairman, education. I believe you have been one of the few people committed to science and technology education for the masses. Your State of New Jersey does more with technological literacy. It is a model State. Nobody else does it. We are talking about the minorities. We are being effective in penetrating to the—it is creating the climate on which good science and technology can be grown, a culture which is not alien to science and technology. That is what we have now created.

Your State, Governor Kean's program—and the State of New York, by the way—New York and New Jersey lead the Nation in technological literacy. It is such a small dollar item; $50 million, a matching program for all the States would really initiate the kind of climate which we must create for getting more scientists and engineers into our work force.

I heard the last gentleman on the work force question. We must not only train Ph.D.'s. That is not the problem. It is the technicians. Germany trains technicians. We do not retrain into technicians. So I think the work force issue is a very important issue. I put the technological literacy one as a cohort of that.

Now to R&D. I think the R&D policies are, we must shift the balance to applied research. I am a basic research type, but we must do applied research, to use it. Our systems for doing it are very, very immature, and I think that we must see—we must fund the creators of those kinds of research.

Let me give you two numbers. The supercollider will cost about $5 billion, let us say. If we go into debt to do that, we will have a $500 million debt a year amortization. Look what I can do for $500 million. I can create 30 or 40 national centers where industry first puts up its money and the Federal Government matches it. It does the kind of pre-competitive research which Japan has shown works. They are a competitive, capitalist economy, but they have learned to do it.

I am to talk about lessons from Japan. We can create 50 centers for the interest in the supercollider. You will have to make a decision. Do you want science which is not relevant to the human economy, to this society, or do you want science which is directly relevant? I suggest that the latter is one of the main things that you will have to wrestle with.

In the universities, we were criticized, very rightly so. I think the research universities—I am sitting on an academy committee—is a very bad model for everybody. The research universities, maybe two dozen, are a damn good thing, but not for everybody. To have a single standard judgment of what is excellent in universities is killing this country. We must have—the land grant system was not supposed to be research universities, it was supposed to serve the agriculture and the mechanical arts. We have given up that value. Why? NSF. Not NSF. NSF is a wonderful institution, but if you have a single source of money, it has a single value system, and that is imposed on everybody, community colleges, four-year colleges, regional universities. They should have different funding sources, maybe a subdivision of NSF, but it cannot be judged by the arcane peer review damn fool nonsense of the research universities.

So there is no evidence that that produces better science. There is no evidence that it keeps us. You see the new discoveries in the fusion, you see the new discoveries in superconductors, you really begin to see that that is not the machine that is the end-all and be-all of humankind.

Lastly, I would say on the question of research support to industry directly, I think it has to happen; I believe in it. I believe that we must be able to support consortia where industry—not to a company but to an industry. We must move more towards a kind of collective support of the industrial sector, and I think that the only way to do that is something that President Carter's Commission on Innovation suggested, a very simple method, matching.

Do not let Washington pick the winners, let industry indicate it. Why should we have an arcane system to get money to a university working with industry? The best field of view is when industry says, "Hey, these guys are pretty good down at Podunk State; we're putting $50,000 in there."

What that Innovation Commission, only staffed by industrial research people, said: "Just give them matching dollars," matching to encourage those universities that really work with industry. No gifts. Research money is the best indication of interest. Now I suggest the same thing be applied to industry. If industry puts its money together, then Government should match that.

Thank you very much, Mr. Chairman.

[Applause.]

[The prepared statement of Dr. Roy follows:]

WHAT WE CAN LEARN FROM JAPAN ABOUT MANAGING NATIONAL R/D

Testimony by

Professor Rustum Roy
The Pennsylvania State University

before

The House Committee on
Science Research and Technology

April 11, 1989

Professor Rustum Roy is one of the country's senior materials researchers. He founded and directed for a quarter century what is the largest materials research laboratory in the nation, and the one which has had the highest percentage of industrial support. He remains closely connected to several leading U.S. companies as a consultant and observer.

A very large number (over 100) of senior Japanese research scientists including university presidents and department heads, and industrial research leaders have worked in his laboratory over the last four decades. He is a frequent visitor to Japanese university and industrial materials research laboratories and has served as an advisor to the Japanese Science and Technology Agency. He has been honored with an honorary doctorate from the Tokyo Institute of Technology.

WHAT WE CAN LEARN FROM JAPAN ABOUT MANAGING NATIONAL R/D

Admiral Yamamoto realized that the attack on Pearl Harbor would "awaken the sleeping giant" of U.S. industrial power. In the present "battle" of technological giants there will be no dramatic Pearl Harbors to awaken us. The first thing we learned from Pearl Harbor was that we were at war: the second thing was that the other side was a technologically sophisticated, major military power.

The analogy must not, of course, be carried too far. We are not at war. Japan and the U.S. fortunately are friendly competitors. Yet the parallels of both these lessons are high on the list of what we can learn today from Japan. I base all my remarks on rather detailed knowledge of the materials technology area only, but know that it is not too different in other fields of technology. Let me start with these two lessons:

1. I do not believe that the leadership in the Executive Branch or in the Congress have fully grasped the status of the competition, "friendly" as it is, for world markets in technology not only with Japan but with Western Europe and soon with many other nations. The leadership's knowledge base and attitudes were shaped in the sixties and early seventies when the U.S. was the unchallenged leader in so many technological fields. For such persons it is difficult to begin to grasp the fact that in many fields of technology there has been a "war" and we have been completely routed (for a complex set* of reasons). "Pearl Harbor" has happened but not as a single event and not on TV.

2. The second point that Japan truly has an exceedingly sophisticated "machine" with a track record of extraordinary technological achievement, is not yet accepted by a large fraction of the scientists, engineers and technological leaders of the nation. But this fraction is drawn from among those that have never been to Japan, or have never seen with their own eyes a variety of Japanese industrial research establishments. I believe that a large fraction of those that have had

*These reasons prominently include the following which are outside R/D policy: (a) the cost of capital, in a culture that has a savings rate of only 3%; (b) The development of the new Wall Street with its LBO's and takeovers which has forced even major corporations into avoiding the long-term investment explicitly demanded by technological R/D; (c) the state of the public's understanding of technology and the litigious American society; (d) the neglect of science and technology education for 30 years even by the science community fixated on machine intensive research.

45

the experiences will agree with my evaluation. **Japanese industry has put together an awesome machine for converting new scientific discovery into marketable products.**

The very first lesson the nation's R/D planners must start with is an accurate picture of the position of the U.S. vis-a-vis the rest of the world in our technological, not scientific capability. In my view, that accurate picture shows that with respect to their industrial R&D capabilities and effectiveness for bringing new products to market, Japan has far outstripped the U.S. Moreover, except for half a dozen major companies (IBM, AT&T, DuPont, etc.) the very suggestion that somehow typical U.S. corporations can compete with Matsushita, Hitachi, Sumitomo, Mitsubishi, Kyocera, Toshiba, etc., brings only a wan smile to anybody that knows the current state of the industrial research systems and the labs on both sides of the Pacific. The most startling conclusion which the data drive me to, which has the most profound implications for national policy, is the following:

The United States is now at a comparative disadvantage in most techno-scientific innovation. By that I mean explicitly, that whenever a new scientific or technological invention occurs, which creates new markets or replaces old ones, the U.S. will typically LOSE market share. In other words every new discovery--like diamond films or superconductors, even if discovered in the U.S.--will be capitalized upon and brought to market faster and/or better by other countries' industries. Thus U.S. policy which is aimed at improving the country's economic position should favor a moratorium or slowdown in scientific and technological "progress." These are radical policy conclusions based on current facts. That is the counsel of realism. I trust the Congress will have them debated on the basis of fact and argument, and not be lulled by the self-congratulation, exaggerated claims, media-hype and victorious announcements on TV news about American science. I note that movies like Rambo do not change the outcome of Vietnam.

These first two learnings are about the relative status of Japanese R/D. We now turn to what I believe we can learn from the indisputable fact of Japanese technological ascendancy. I do not believe that the Japanese are ten feet tall, have performed miracles, or are unbeatable; nor do I

believe that we should copy anything from Japan. Learning from, and adapting ourselves, and copying slavishly are very different responses. I group the subjects within R/D policy in which we can learn from the Japanese experience into three or four areas and present them below.

1. Technology Policy is Vastly More Important than Science Policy

For forty years since WWII, the U.S. has had NO civilian technology policy. In effect we have assumed that the private sector can handle that unaided. The U.S. has had a generous, albeit undemocratic "policy" for science, run more or less exclusively by the beneficiaries of the policies, i.e. the scientists themselves. Events have proved that the U.S. choice has been very wrong. If the goal was to have a healthy science and technology we clearly have missed it by a wide mark. We do have an effective (though not cost-effective) machine to produce science, but have so far ignored (civilian) technology.

The reason for this U.S. error is now well established. U.S. policy was sold repeatedly to Congress year in and year out (see Shapley and Roy, Lost at the Frontier, ISI Press, 1985) on the assertion that "Science leads to applied science which leads to technology." This grossly erroneous view of the process of innovation is still held, and repeated, by many scientists and policy leaders (including G.A. Keyworth, Science Advisor to President Reagan). It is certainly still believed by the vast majority of laypersons inside and outside both the Executive and Legislative branches. Note that most of the persons who hold such views have never seen the inside of a Japanese research establishment. The reality of the excellence of the Japanese technological establishment--quite apart from the economic issues--is living proof that this basic assumption underlying U.S. policy was and remains a devastating error. Figure 1, taken from a study done by the Congressional Research Service, is one of the most dramatic disproofs in history. U.S. policy has indeed succeeded in building the machine which produces research papers in journals and wins Nobel Prizes. But Fig. 1 demolishes the premise on which 40 years of policy have been built that "science leads inevitably to technology" (Keyworth, 1985), because the data in the figure show a negative correlation between winning Nobel Prizes and increase in

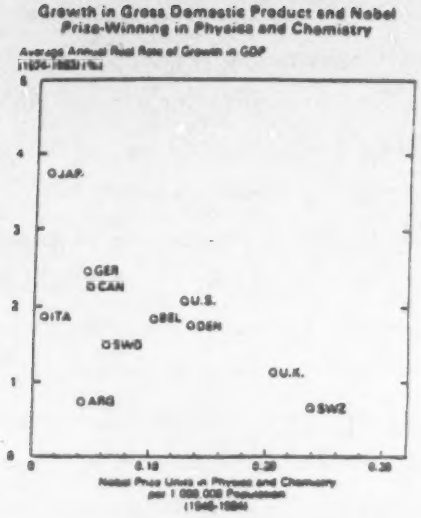


Figure 1. (From C. Hill, Congressional Research Service).

Gross Domestic Product (GDP) of a nation. Since the war Japan has won four Nobel Prizes, the U.S., 150. Our technology at the same time has slipped disastrously on the world scale.

The Japanese in radical contrast to the U.S. have focussed the national R/D issues on technology, with "science," especially university science, as an afterthought. Indeed the order of policy attention is Technology: (Science and Technology) Education; Science. The M.I.T.I., The Ministry of Education, and the Science and Technology Agency come in that order, in policy making importance. I believe that the next key learning from Japan is that we must focus national policy making attention on civilian technology policy. Science policy, i.e. NSF and NIH budgets are not the relevant measures in sizing up how we're doing in technology.

2. Cooperation and Collaboration is Much More Effective Than Competition in R/D Matters

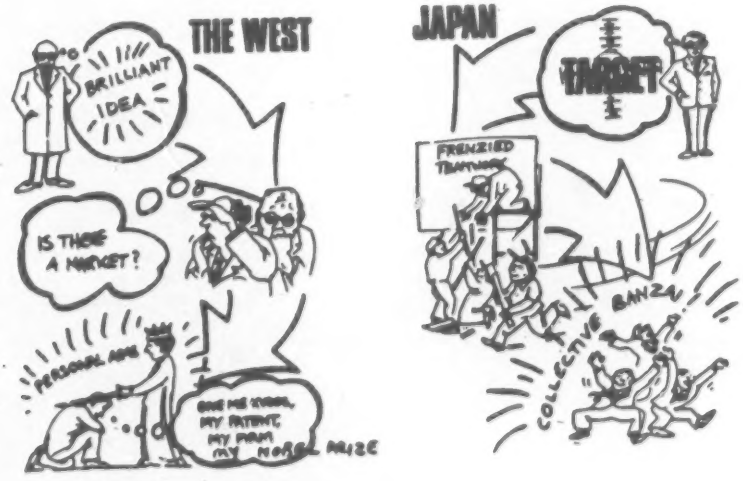
The funding structure we have created in the U.S. with its elaborate bureaucracy, and grossly inefficient (not necessarily unfair) system of awarding grants protected by religious

48

incantation of "peer review" as a panacea, has been built on a false premises. The premise is that "competition" among (largely) individual scientists is the way to get good science done in a nation. This leads to (a) an enormous waste of national talent in the arcane processes of proposal writing and marketing; (b) an uneven support of all groups and individuals, which simply doesn't correspond to the way the best science gets done. It's like replanting half the apple trees in the orchard every three years: few last long enough to bear any apples.

University research in Japan, though very modestly funded by our standards, has much more stability to it, and much more long-term planning in 5-7-10 year modules.

Basically in many science and engineering areas the Japanese R/D planners do capacity-based planning. That is, they size up the strengths and weaknesses that exist, and create an inter-digitated set of research programs to address their target goals. For example the superconductor joint research program started at five universities was in its fifth year of a collaborative 5-year effort, when the new high T_c materials were discovered. Hence they could move in very fast. Typically tasks are re-programmed after about 5 years; the same team may continue on the same goal, the goal modified, or the people re-directed.



THE ECONOMIST APRIL 30 1988

3. R/D Policy is Target Driven Not Idea Driven

The cartoon perhaps makes the point as well as the text will. The U.S. national R/D culture is highly individualistic whereas technology requires a team mentality. For forty years U.S. national policy makers have gotten off easily by justifying the success of "free market," "laissez-faire" approaches by comparing ourselves to the USSR. But every technologist who was at all familiar with the USSR knew that they were a disaster-area and moreover that they did NOT plan R/D nationally. Our competition has, in fact, always been Western Europe and Japan. The fact is that the U.S. model of private sector competition, to drive technological innovation, which was only valid and very successful into the late sixties and seventies because of the unique and anomalous situation of U.S. dominance after the war, now is simply outmoded and highly counterproductive.

The nation must figure out ways by which we can articulate national and private sector goals in the civilian technology area. The Japanese processes have been thoroughly studied and described in many books and reports. I will not attempt here to digest these or recommend among them, but only point out that a U.S. articulated national policy for civilian technology policy is a must. Unfortunately this is so new to the American experience that the Congress will not easily be able to achieve consensus on this. Yet it must make a start NOW, since every year sets us back further. It must also be realized that many multi-national corporations with HQs in the U.S. are doing financially very well for their stockholders (only a fraction of which are U.S. citizens) by NOT having such a civilian technology policy and off-shoring more and more of their production. Hence a good fraction of the industrial R/D sector may or may not be particularly supportive of national planning for the benefit of U.S. citizens and the nation's jobs and our national institutions.

4. In Japan Yen Investment by Industry in R/D is the Pre-cursor and the Absolute Requirement for Government Investment in a Particular Area

For years U.S. R/D policy makers comforted themselves, without looking at the data, that it was huge "Japanese government subsidies" which was behind the success of Japanese

technology. We know now that this is the opposite of the case. For whatever complex of reasons (noted in my first page) the fact is that Japanese industry has been much more willing for the last decade or two to invest in new high risk technology. Subsequent to such decisions the government steps in, with a bottom-up and top-down iteration of planning, and the creation of appropriate industry collaboration structures, and then the provision of some "matching funding." The U.S. model of supporting research in an industrial laboratory which is not putting any of its own money into the field, and probably has neither the interest or capacity to market any products, would be inconceivable in Japan. This is the worst possible waste of Federal R/D dollars.

In the U.S. we have created an enormous research machine not only in the universities, but in not-for-profits and within many industries which exist NOT to make products but to consume Federal research dollars, a profit-making product itself. This research machine not connected to product must be re-examined.

This is the one area in which a pinpointed policy can make a big difference. It can be achieved very simply by introducing legislation to assure that no industrial research laboratory receives any Federal research money, beyond some fraction of the amount they themselves invest. The logic is impenetrable. If the company focusses on the product it can make, and plans to invest the large sums necessary to bring a lab-scale invention to the marketplace, it certainly will invest a certain amount in long-term research. It is in this area of pre-competitive research that the Japanese government has been very creative. It is not only that they provide some matching money for research within industry but they catalyze and encourage the creation of an infrastructure for collaboration. The fact is that their system is working: ours is not. Companies can collaborate at the pre-competitive level with or without universities and government laboratory involved in the structures, and yet compete vigorously at the product level.

5. The Role of the University is Focussed on Education, with a Minor Role in the Total National Research Effort

The linking of government funding of higher education--without any competitive proposal writing--directly to the Ministry of Education creates a much greater focus on education rather than

diverting attention, as in U.S. universities, to seeking research funding and doing research as a means of bootlegging support for education.

The U.S. has put a lot more of its total R/D funding resources into its universities than has any other "developed" nation. This has resulted in the following unfortunate side effects.

a. It has radically degraded all aspects of education, including science education of the majority of the population including the nation's lawyers, business and political leaders, etc..

b. It has built up a large political constituency which relies financially on the Federal dole--and yet is quite inattentive to R/D goals of the nation.

c. It is extremely difficult to bring back balance into the university research effort among fields, between untargeted basic and targeted basic research. If fields like particle physics and radio-astronomy have been grossly over-emphasized in the past, they now feel an "entitlement" to continue these unbelievably expensive kinds of research irrespective of the national well-being. Congress is so bamboozled by the rhetoric that it fails to ask the simplest questions of what conceivable good such public expenditures can bring to the American public.

d. Grossly exaggerated hopes are built up on what can be achieved by university-industry coupling, etc. Such coupling is indeed important, but it is a very small factor. Moreover, many university-industry programs are NOT driven by a market or product orientation, but based on the old science-based bureaucratic model designed to preserve government jobs. President Carter's Innovation Study provided a perfectly workable model recommended by leaders of U.S. industry. Stated very simply--and here it follows Japanese practice--it said that the best possible "peer review" of that part of university research which is relevant to industry is whenever the industry finds the best university partner and puts down dollars to back its research in a certain area. The relevant U.S. agency should simply provide the system to match these targeted industrial dollars in some reasonable ratios.

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6. The Japanese Focus on Engineering Education in Very Sharp Contrast to Our Emphasis on Science

The figures are quite startling. Either the U.S. produces too many scientists, or far too few engineers, or the Japanese have got it all wrong. The U.S. ratio of (science degrees)/(engineering degrees) is 8.5 times greater than the same ratio in Japan. It is likely that we will not be able to expand soon the total number of scientists and engineers. However, by incentives and re-training programs we could easily convert a reasonable percentage of the science cohort into applied scientists or engineers.

SUMMARY OF U.S. POLICY RECOMMENDATIONS THAT COULD RESULT FROM JAPANESE LEARNINGS

The foregoing suggests that the U.S. can indeed observe the Japanese experience and learn a great deal from it. A question which was addressed in earlier hearings before this committee asked how this is best done. Many of the witnesses including myself supported the simple expedient of sending U.S. engineer and scientists to Japan for two-week and six-month stints to visit labs of all kinds.

It is beyond dispute that where we were mistaken in our "theories" of how science relates to technology, we must change and soon. This is the case for the basis of our R/D policy, right through the Reagan years: the idea that supporting "basic science" will by itself help U.S. technology. It is almost the exact opposite of the truth. The U.S. already has a superb science-producing machine; what it badly lacks is a science-utilizing machine. Producing even more science can IN NO WAY WHATSOEVER help with science utilization to make products. Indeed most of that science will be utilized by Japan and Germany's superior science-utilizing machine. In such areas Congress must start from scratch to build new policies on the solid ground of reality.

If R/D policy makers in Congress respect the insights reported above I believe U.S. policies would move quickly in the following directions:

53

Non-R/D Issues

1. Tax structure changes which favor long-term investment; and explicitly reward technological job creation in the U.S. A sliding scale starting from say 95% for investments held less than one year to 5% for those held for 10 years would strongly favor a new industrial technological revival.

2. Engineering and science education should receive a higher fraction of Federal university funding even at the cost of research. Within that, two objectives should be separated and funded separately.

a. Increasing the quality and quantity of the technical workforce from technicians to PhDs.

b. Increasing the understanding of science and technology by nonscientists and its integration into popular culture and values.

R/D Issues

3. Immediately shift balance of R/D funding towards that purpose-linked science which is clearly and directly, albeit in the long (i.e. 5-10 yr.)-term, related to industrial product development. This does NOT mean shutting off the blue-sky small project science such as that which led to the major discoveries of electrochemical fusion, new ceramic composites, diamond films and superconductors. It DOES mean shutting off mega projects like the SSC. It also requires reconfiguring the university system in the U.S. (see below).

4. For just the annual interest ($500 million) on the additional debt to be incurred to build the proposed supercollider, the nation could do the following:

Establish 25-50 National Centers for pre-competitive long-term research to support 25-50 families of industries. Each of these would be funded by matching these Federal dollars for industrial contributions. Each could be built near, but independent of, a major university center.

The model of creating industry associations, and providing matching money for R/D for the industrial contribution, is a key.

This is the kind of choice the Congress must make--build a supercollider to advance science or creat a few dozen national centers funded at $20-40 million per year in perpetuity to support technology.

5. The monolithic structure of U.S. academic research must be made more diverse. At present the artificial values of the research university are distorting all research funding towards less industrially relevant work. The U.S. should have 20-25 world class departments in various universities doing the frontier world class research. These should be funded from one NSF pool. The more applied and relevant to industry engineering and science, the province of the traditional land grant institution should be funded from a different funding pool. It has different values and objectives from the science-laden values of the research university.

Finally, other small science research and small college research (mainly justified by its value to training) should be funded from a third pool.

Different agencies, or clearly isolated areas within this same agency, must be responsible for the different pools of funding.

6. In all cases where university-industry coupling in research is involved, the matching principle should be the basis for university funding. The Federal government should not attempt "to pick winners," it should provide a match (in ratios from 7:1 to 1:1) for the hard research dollars which after the most stringent peer review, are contributed by industry to the research program at the university.

The CHAIRMAN. Well, Doctor, I want to thank you. Is that the announcing of your candidacy?

Dr. ROY. I do not know for what, Mr. Chairman.

The CHAIRMAN. Questions. The gentleman from New York, Mr. Scheuer.

Mr. SCHEUER. You just gave us some fascinating public policy issues to face up to, Dr. Roy, and the spontaneous applause that you just heard is something that is rarely evoked around here. So we are all grateful to you.

You said we do not have that machine any more. Can you characterize the machine that we may have had but which we have now lost?

Dr. ROY. The machine was evidenced in our AT&T. The grand old AT&T was a chain-linked machine where the product drove the basic research. The idea that people are sitting around dreaming stars in AT&T is not right. Bill Baker is a good friend of mine.

If you looked at the AT&T machine, it went basic, relevant basic, long-term applied, short-term applied, product-oriented. That was the machine. And I go to Hitachi, I go to Sumitomo, and I just cry. My God, they have got it over there, and I can not find, I can not name more than six companies here which have the machine any more, because of this buy-out business. If the guy is really sitting on accumulated knowledge, the raider comes in and says, "Aha, I can make the pieces worth more than the whole"—that was the old machine. It is an American invention. It is the grand old U.S. invention.

Mr. SCHEUER. You were talking about the superconducting supercollider, and you were saying—I think you were, if not saying, suggesting, that on a cost/benefit basis there are other investments that we could make with the interest on $5 billion, perhaps $500 million, that would have a greater impact on putting together this machine on advances in science and technology. Is that more or less your view?

Dr. ROY. Yes. Mr. Chairman, he has used the term "science-based technology"—I actually used that 15 years ago with the Pope—and "issue of the science-based technology" means that we can really make something out of the science. With the supercollider, with a lot of dreaming, you can talk in the future, maybe something will come out, but we are not ready for maybes any more. The supercollider should be built, it should be built internationally, it should be built as a genuine cooperative venture. Let the Japanese pay the bill; they are willing to.

Mr. SCHEUER. Well, we visited CERN just outside of Geneva, and we were impressed with what was going on there. I suppose some of us feel that we can not afford to stay out of that whole future field that would be developed from the superconducting supercollider. We do not want to be denied admission to that ball park.

Do you think that there is some way we could continue to participate in CERN, perhaps on a bigger scale?

Dr. ROY. Absolutely, I think, and if we should design the next generation machine we should be doing it cooperatively. My friends in Japan tell me this following sentence. They say, "We are not usually a cooperative in the sense that cooperation means we get in on the design phase, we get in on the site selection." If we are

going to pay the bill, we do not build a machine and then say, "Hey, fellows, put in some money." That is not cooperation, that is Big Brother.

I am certain that the first step is CERN, greater participation. The second step: Design a genuine international machine with the Soviets collaborating, with the Japanese paying a good part of the bill, the West Germans. Design it collectively, and build it somewhere else, and maybe somebody will come up with fusion, little tricks. What Freeman Dyson says is we are not thinking enough; this is all engineering; that is not science. Think. Maybe some new ways of getting there will be possible. So I think we have got a little lead time.

Mr. SCHEUER. If you were given a fund of a billion dollars to encourage science-based industry, how would you spend it? What would your priorities be?

Dr. ROY. I would put $50 million into Mr. Kean's replicated thing for technology literacy, just a matching grant through the state. It is only $50 million. Now I would put at least 50 centers into operation right now. We are losing industry. It is cheaper for me to save a job in America than to create one. I would target industry. You have got to target; you've got to say, "I can save this baby." Okay. I will have a university-industry consortium not under any damn fool universities; you can not trust them; you have got to have it outside the university structure—

Mr. SCHEUER. But involve the university.

Dr. ROY. But related to the university and contiguous to the university, and relate that to a particular industrial sector—the glass industry, the shoe industry, whatever it is. We must target and we must save. This nonsense of saying we can not pick winners and losers—we can at least pick—we do save babies that are dying; we have got to save some of our industries.

Mr. SCHEUER. There has been some discussion that the antitrust laws that were relevant to the problems of a century ago, in the 1890's, where we wanted to maintain competition, are not only irrelevant but damaging today, because the question may be not whether we are going to have three or four automobile companies in America competing for the American market, but whether we are going to have one automobile company or consortium that can be an effective competitor in global trade, and for that we may need some kind of joint enterprise not only in research, for which we have jiggered the antitrust laws now, but in actual development, all the way through the process—research, development, production, marketing, sales, the whole schmeer. Some people are saying we have just got to shuck off the antitrust laws for at least specific targeted industries. It may be the same in consumer electronics, it may be the same in high-definition television, HDTV.

Can you give us your observations as to the relationship between the current antitrust law and the kind of integrated process that you are looking for?

Dr. ROY. I think the antitrust laws do need modification, careful modification. I think in the research area sometimes the companies have used it pretending that they were going to be attacked. I think in the research area that has gone. I believe I would move carefully in the direction of eliminating some of the antitrust re-

strictions on getting people together at this point, because the world economy is such that an American company does not dominate any market any more.

Mr. SCHEUER. Thank you, Mr. Chairman.

The CHAIRMAN. The gentleman from Oklahoma, Mr. McCurdy.

Mr. MCCURDY. Thank you, Mr. Chairman.

Dr. Roy, you are a delight, and we are glad to have you here. I come from a football school as well, the University of Oklahoma, but we are not doing too well right now. But the last time we won a national championship was against Penn State in 1985.

I really applaud you for your statement, because there is so much in it that, I guess, matches a lot of the statements I have been making across the country in talking to different groups. And I venture—you know, sometimes it is better not to ask a question if you do not know the answer beforehand, but one of the statements that I have made, and I want to know whether you agree, because it appears to me that some who are focusing so much on the Japanese, that their response is usually one that involves protectionism—build up barriers, and it is, you know, buy time—as opposed to a more positive approach, which is investment strategy: How do you get this engine running in order to compete? It is not a problem that, just because theirs is so good we need to put up barriers. What we need to do is invest in ours to get us up to the point that we can compete more effectively.

So you are not advocating protectionism, what you are advocating is, how do we get the most out of our investment? And that you need some structural change more for technology science, applied science, engineering science, those kinds of things, which we do not do well. I happen to advocate a civilian DARPA—you know, some other types of approaches at the Federal level.

But one area that we do not get into, and I do not know whether you are versed in this area or not, and that is, we try to do a lot of things on this committee, but we are limited. The people that really have the authority and power in this Government are those over in the Ways and Means Committee, the guys that write the tax law.

To me, to get at this buy-out problem—and I could not agree with you more; we are selling off American industrial equity, is what we are doing; we are just incurring debt in order to fend off a few very greedy people; and there is nothing wrong with, you know, capitalism or greed; I am just saying that the system is not working well right now.

Are there any policy recommendations you have as far as more of an investment to encourage savings, productivity, and investment that perhaps are in the tax area?

Dr. ROY. I am sorry you started with a reference to Penn State losing to Oklahoma, but, in fact, I have seen your statements on the civilian DARPA, and I thought I had coined that. But I really feel you talked about two things; one is structural changes. You can make them. That is within the province of this committee on the R&D sector that we've really got to make. There is a Pearl Harbor. We have got to make some structural changes, and you have alluded to one like that.

But I think, beyond that, I believe that the chairman also started with the questions of savings rate: What can we do to encourage savings rate? B: What can we do to stop buy-outs? Of those two, I think the policy interventions can come much earlier in the buy-out mania, because if we do not stop buy-out mania the incentive for—American industry is not stupid; all they need is the proper structure within which they are protected from their great investment in research. If they do not invest for 10, 15 years, they can not possibly make out.

I am not enough of a lawyer to make out tax structures, that I defer to Ways and Means, but that clearly must be done. It is something that this committee has to say that our industry is going down the tubes if we do not do it.

Mr. MCCURDY. Well, I agree with you, and that is something that perhaps we do not preach enough from this committee, but we need to be out there, and I commend the chairman for holding this hearing.

One last question, and, again, I am one in the minority on this committee, I happen to agree totally with you on the SSC and have voted that way, much to the chagrin of my leadership here. But I am concerned, not that I am against the technology, I would love to have the basic science as well. The question is, how do we take what few dollars that we have available to us and distribute them enough so that they hatch productively and create new wealth? I tend to agree with you on that one.

Dr. ROY. Mr. McCurdy, I hope you win your fight in this committee, because I really feel it is Pearl Harbor Day, and there are some things have happened, and if you would go and see what the Japanese machine is like, you would be willing to make those decisions.

I think we can defer the supercollider; I do not mean collapse it, but defer it, and get on with these other issues.

The CHAIRMAN. The gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. Again, Mr. Chairman, this testimony is terrific and thought-provoking, and, again, I thank you for bringing us together today to hear these witnesses.

First of all, I would like to ask this witness whether or not, in terms of stimulating our own companies to involve themselves in long-term research, do you think it would be better, rather than the matching funds which you have suggested, which tends to put companies through a certain amount of time and effort that naturally comes with political—something that involves a political decision of government, of a Government agency or bureau, would not it be better to provide tax credits for long-term research rather than trying to put all of our companies through this kind of political machinations in order to get money for their research?

Dr. ROY. No. I completely agree with you. I do not want them to go through any political machinations, first.

Mr. ROHRABACHER. But that is inherent with matching funds, is it not?

Dr. ROY. No.

Mr. ROHRABACHER. When you have a political group who are making decisions what funds are going to be matched and what are not, people are going to be jumping through political hoops.

Dr. ROY. No. I agree with the investment credit for long-term R&D, absolutely, no question, but (b) when more than one industry is involved, a consortial effort, there the matching fund formula should be laid out. It is given to a university. If six companies give $50,000 each to the university, that pool is augmented, and thereby the industry is given some incentive to go into that pool by saying, "My $50,000 will be matched by many others."

We have a diamond program at Penn State; we brought the diamond films to this country. We have 32 companies putting in their money. The Navy brought this to the country. They supported us. Now, essentially, we have an unofficial match. The Federal Government is doing the basic research, but we have 32 companies. Every year, they are going to make that decision and plant down their money. I am saying that is the kind of match in selected areas. But I certainly would not rule out the investment tax credit; I would put that very high up.

Mr. ROHRABACHER. Okay. And just for the sake of being the only one here who seems to be the champion of junk bonds and buy-outs today, I mean, this idea that people are expressing—and with all due respect to the chairman and the other people who have expressed themselves on this issue of buy-outs today—would not you be a little afraid of protecting the management of certain corporations from buy-outs when it might make them very comfortable rather than energize them to be more innovative?

Dr. ROY. I sit, at least an advisor, on many corporate boards, and they are so damn scared today. There is not anybody left, Mr. Rohrabacher, of that quality any more. The corporate managements that were fat and lazy have been bought out.

Mr. ROHRABACHER. Well, is not that a very good benefit of these type of buy-outs?

Dr. ROY. But by going too far it has now eroded the entire research, applied research, development structure, to where no company is willing to do it any more.

Mr. ROHRABACHER. But is not the money that is being, quote, sucked out of this system, is not it going from inefficient companies? If you have a company that is undervalued, and which it is in itself a definition of inefficiency of the management, is not that money going into the marketplace where it can be invested, perhaps, in smaller companies that do not have such high overhead as these large corporations may have?

The CHAIRMAN. Will the gentleman yield on that point?

Mr. ROHRABACHER. Yes, sir, certainly.

The CHAIRMAN. Let me tell you, when you look into the background here—you have been pressing that point, and I think rightfully so, because you are talking about the inefficiency in management, and part of what you say is correct.

However, these raiders, for example, now, they are taking the pension funds. In one company, it is $500 million, where the people put the money up over a period of 20 years, and the laws are very silent on that issue. They can literally divert this. There is a suit on it now, but they can literally divert that $500 million to almost

what they want. In other words, they will short it. They will say, "$125 million is enough to finance that pension system; we will take the other $375 million, and we will use it as part of the acquisition, or we will use it for what we want to use it." This runs into billions and billions of dollars of pension money. That area alone is an area that this Government ought to be worried about.

I yield back, of course, to the gentleman.

Mr. ROHRABACHER. I would just answer that by saying of course we need to protect pension funds, and of course if they are taking funds that were set aside for something else and are being used by corporate raiders, there's something wrong with the structure of the system.

But declaring that people who come in and try to buy out management of major corporations and try to protect management from what would be people who would come in and do a better job perhaps and use that company more efficiently, we can be basically, in the name of protecting long-term research, we can be ending up making comfortable management that should not be comfortable.

Dr. ROY. But, Mr. Rohrabacher, may I respond in saying I take your point on efficiency which is gained by the threat of buy-outs. But let me give two analogies. One is, you do not want to sell the seed corn. If we are now selling the seed corn of our future in saying, "Look, we can make some money on the seed corn," we are killing our future. The second one: I think you could fine-tune the adjustments. I believe you could do one on the question of shutting down companies, shutting down—when GE bought RCA, to shut down that great laboratory was a loss to the Nation, and I think you could fine-tune it. But I think the chairman is right, most of this now is for making money for the raider and not for the health of the economy.

Mr. ROHRABACHER. Well, absent money that is being sucked out of these companies, out of their pension funds, but the money that is coming out of corporations that are undervalued, is not this money just being reinvested into other companies? This does not evaporate, it becomes part of the productive system of our society and perhaps is channeled into smaller companies that are more efficient by investment.

Dr. ROY. It is not my expertise, but I have never seen any of that reinvestment on the scale which this country needs to recover its industrial base.

Mr. ROHRABACHER. Okay. Thank you very much. Thank you, Mr. Chairman.

The CHAIRMAN. The gentleman from Connecticut.

Mr. SHAYS. Thank you.

It is not fair to say that an undervalued company, by definition, is inefficient. I mean you would not agree with that, would you?

Dr. ROY. No, no.

Mr. SHAYS. I mean a company could be making long-term investment in terms of capital—long-term investment in terms of research that then tend, in the short run, to undervalue itself.

Dr. ROY. Indeed. In fact, that is what I meant by the seed corn analogy. If you have stored up a lot of bags of seeds for the next few years, it would not be fair to call that undervaluing.

Mr. SHAYS. I realize it is a little out of the subject, but it is so related to the subject. I mean a little—not your expertise, but I mean just take Prime America, which is next door to—in my district. The top nine or ten executives made millions of dollars each.

I had Champion International come and talk to me, and the owner—the CEO of the company said, "I could make over $50 million by the sale of this company," and what he is describing to me is that management now begins to maneuver for buy-outs and makes sure they structure their contracts so that if there is a buy-out they do really well.

So we have got some major problems, and I really agree with the chairman that if we did nothing else but deal with that issue we would be making some progress.

I would love to just understand one part of your testimony, and I appreciate you speaking in terms that I can understand, not necessarily with football analogies, but I also want to say, in the 14 years I have attended public hearings, I consider your testimony the most valuable that I have ever heard in the 14 years, not necessarily here but in general, and I appreciate it, and I know you are well known around the country. I am just happy to have finally met you, and I would hope that you would have some direct interaction with the administration, because they need to hear what you have to say, as well as those who spoke before you.

I am just trying to understand your concept that, you said it is easier to keep a job than it is to create a job, less expensive, and I need to just very briefly have you explain to me. I have accepted the fact that we are going to become a service economy and that is where the future jobs are, and I began to think, well, why does that have to be? I mean is manufacturing, by definition, no longer relevant?

Dr. ROY. No. I am a member of the National Academy of Engineering. We wrote a nice booked called "Manufacturing Matters." I cannot believe we can be a 100 percent service economy. That is absolute nonsense. We have to produce goods and services, and the goods part is where it gives us our wealth-creating power.

I think that our potential for saving jobs is as follows: In St. Mary's, Pennsylvania, a little hick town in the north of Pennsylvania, we had the magnetics industry, and we could have saved that magnetics industry by giving them the kind of R&D, precompetitive support, which would have cost five or ten million bucks a year. It was centered there, but it is a nationwide industry. We did not do that, so slowly the Japanese competed, the West Germans competed, and we lost that market.

What I am saying by that allusion is, by creating, by targeting that industry, saying we always need—we are going to need magnets—for God's sake, we are going to need them—we should be producing magnets. We will continue to have a magnets industry. Now that is not by subsidy of the industry, but it will be by saying the precompetitive R&D. Force some of the universities to get off their high horse and work on problems relevant to the economy, and match it with Federal money. Make sure the industries contribute to it. That could save the magnets jobs rather than try to create a new high-tech or low-tech industry. I believe we should never focus on high-tech.

We have now lost a comparative advantage in science. This is the most important policy statement I am making. Every time there is a new science discovery, America will lose market share for the next 20 years, every time. If fusion comes, we will lose market share. If we get room temperature superconductors, we will lose market share, even if we make the discoveries, because the machine that uses that information is out there now. We have got to reinvent that machine. So that is what I am talking about. Where we have the machine, for God's sake, do not throw it away.

Mr. SHAYS. As it relates to this machine—and you describe only a few companies—I guess I am to view your description of this machine in a micro sense. Those companies that can use the technology efficiently and effectively to produce a product is that machine you refer to?

Dr. ROY. Exactly, that can take new knowledge and make a product. The real world.

Mr. SHAYS. I do not see any hope that a company is going to get back into that, because it seems to me like a very long-run kind of decision, and you made me more pessimistic than I was when I heard the first person. Tell me something that I do not have to be pessimistic about.

Dr. ROY. I think what was said about saving is precisely your pessimism. I believe we can save the ones that still have the machine to create a new one.

Mr. SHAYS. Are there many of them?

Dr. ROY. There are still a few. Our manufacturing sector is about 23 percent. We are not that badly off. But every day it erodes, and I think that we should intervene quickly to save that, what is left of the machine. I think that you are right on the new ones, it is going to be very difficult, until we change the culture.

Mr. SHAYS. You leave me speechless, and that does not happen often.

Thank you, Mr. Chairman.

The CHAIRMAN. All right. Dr. Roy, thank you very much for your patience. I really appreciate your testimony a great deal today.

Our next distinguished witness is the Honorable Dr. William R. Graham, who is our Science Advisor to the President.

Dr. Graham.

Again, it is unfortunate that we have such good witnesses today and those who have so much they are adding to the committee that it is taking us a little longer.

May the chair express to you my great admiration and high respect for the outstanding job you have done as a science advisor to the President and the great help you have been to this committee over the years. We want to thank you very much, Dr. Graham, so go ahead and start your testimony.

[The biographical sketch of Dr. Graham follows:]

THE WHITE HOUSE

WASHINGTON

DR. WILLIAM R. GRAHAM
Science Adviser to the President
and Director, Office of Science and Technology Policy

Dr. William R. Graham became Science Adviser to the President and Director, Office of Science and Technology Policy, on October 2, 1986. Before assuming the duties of Science Adviser, Dr. Graham was Deputy Administrator of the National Aeronautics and Space Administration, from November 25, 1985.

Dr. Graham served from 1982-85 as Chairman of the President's General Advisory Committee on Arms Control and Disarmament. In 1980, Dr. Graham served on Presidential candidate Ronald Reagan's Defense Policy Advisory Group and was a member of the President-elect's transition team.

Dr. Graham was a founder and senior executive of R&D Associates, Marina del Rey, California. He worked six years with the RAND Corporation, Santa Monica, California, and for three years was an officer at the Air Force Weapons Laboratory, Kirtland Air Force Base, Albuquerque, New Mexico, directing experimental and theoretical research on the effects produced by nuclear explosions.

Dr. Graham has been a consultant to the Office of the Secretary of Defense and has served on many international and national boards and advisory groups, including the National Academy of Sciences/National Research Council Committee on Undersea Warfare, the Air Force Science Advisory Board Task Force on Manned Strategic System Vulnerability, the U.S.-U.K. Joint Working Group on Atomic Weapons, the Defense Nuclear Agency Scientific Advisory Group on Effects, and the Defense Science Board System Vulnerability Task Force and Associated Task Forces.

His memberships in professional and honorary organizations include Tau Beta Pi, the American Institute for Aeronautics and Astronautics, the New York Academy of Sciences, the Council on Foreign Relations, the Board of Directors of the Committee on the Present Danger, the Defense Preparedness Association, the Ethics and Public Policy Center, and the American Association for the Advancement of Science.

Born June 15, 1937, in San Antonio, Texas, Dr. Graham earned a B.S. degree in physics, with honors, from the California Institute of Technology in 1959. He earned an M.S. degree in engineering science in 1961, and a Ph.D. in electrical engineering in 1963, both from Stanford University. He and his wife, Nina Winter Graham, have two children.

STATEMENT OF DR. WILLIAM R. GRAHAM, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT, WASHINGTON, D.C.

Dr. GRAHAM. Thank you very much, Mr. Chairman. I appreciate the opportunity to testify before you on the subject of creating the new wealth R&D funding in the 1990's.

In view of your time schedule, if I may, I will submit my entire testimony for the record.

The CHAIRMAN. If there is no objection, it is so ordered.

Dr. GRAHAM. In fact, it addresses a number of issues, such as the increasing level of Government support for science in this country and, in fact, for research and development. It talks about the international cooperation and competition in high technology areas that we are engaged in, and it addresses the effective utilization of the intellectual and physical resources that we have in this country, and, of course, I would be glad to discuss any of those during the questions.

But in keeping with your guidance in your invitation, if I might just focus my brief comments on our aircraft industry and the Aerospace Plane in particular.

Earlier testimony mentioned the comparison of military R&D and how it contributes to our nonmilitary goals. Of course, the 707 is the classic case. A few other facts associated with it were that the Boeing Company bet $15 million, 27 percent of its net worth at the time, on developing simultaneously the KC-135 stratotanker and the 707 aircraft. It was first among its competitors with that concept and was successful then in following up quickly with the 727, the 737, 47, 57, 67, and it still has new derivatives in aircraft on the drawing boards.

This aggressive approach, which has reaped the benefits of military as well as civilian development, has resulted in a clear world leadership position today for the U.S. in commercial aviation. Today, we have a $75 billion backlog of orders nationally in commercial aircraft and a net high technology trade surplus in commercial aircraft of over $18 billion a year. The Government, taxpayer, military, and the industry have all benefited from a number of commercial and military derivatives from these aircraft.

But let there be no doubt. This technology will not stand still, and unless we vigorously pursue the technologies that will dominate air transportation and aircraft in the next century, others will proudly point to their foresight and their leadership rather than us to ours.

But thanks to the pioneering efforts of DARPA, we now have a major platform being established for advanced aerospace transportation in the National Aerospace Plane Program. President Bush strongly supports this program that was introduced by President Reagan in his 1986 State of the Union address. Many Senators and Congressmen from both parties, especially, I might note, the distinguished chairman of this committee, the ranking member, and many of the other members of the committee are on record as strong supporters.

The NASP is a highly significant longer-range research program that will advance affordable access to space by developing a flight

vehicle that can operate from a runway through the flight regime all the way to orbital velocities, and follow-on operational vehicles will certainly complement the space shuttle in expendable launch capabilities and add greatly to the increased capabilities of our access to space while possibly reducing today's launch costs and complexities.

Of course, follow-on vehicles—follow-on to the X30, the aerospace plane—will also afford NASP-derived vehicles that can be used in the civil and commercial sectors not only for space transportation and access to such infrastructure as the space station, but also for long-range transport.

Military applications will change the way we do business as space and short-notice access to it become more and more the ultimate high ground. The Orient Express is the hypersonic civil transport which may be a follow-on vehicle to the NASP The Orient Express research, and especially development, should ultimately be pursued by our industry, not by our Government, as a commercial product.

The technical challenges are substantial, but today the NASP team comprises approximately 5,000 members of the U.S. Government—DOD, NASA, and National Laboratories—also members from our universities and our industries, led by General Dynamics, McDonnell Douglas, Rockwell, Pratt & Whitney, and Rocketdyne, and many, many contractors in tiers beneath them.

The real success story of the NASP program, in my view, is how the five prime contractors competing for the airframe and engine design have united in a materials consortium to pool their resources and share the progress in required materials. They are also addressing other areas for teaming, such as common subsystems and eventual management of the X30 program.

We see the results of what cooperation can accomplish in some areas by watching competitors, like Europe and Japan. In Government, we must make sure that we help our Nation compete by encouraging companies to work together on larger programs, such as the NASP, and in that regard it is worth recalling that the antitrust laws were designed to promote competition, to avoid restraining competition and trade. Nevertheless, today, in a quite different environment than the one that they were conceived in, those antitrust laws as often help to suppress competition as to promote it, and I certainly believe they need review and change.

The NASP program is bringing about Government agency cooperation between the Defense Department and NASA. It is bringing about Government-to-industry cooperation, and, finally, it is bringing about industry-to-industry cooperation. That cooperation in all sectors has been so strong that, to date, industry has invested approximately $500 million of its own money in the NASP program.

Industry certainly considers this a vital program, but so do Japan, Europe, and the Soviet Union, who all want to participate in this very aggressive technological effort. Since we are in the lead, we can be very selective about that cooperation. The National Aerospace Program, with its broad bipartisan support, provides a rare opportunity for the U.S. to leapfrog our current technical capabilities and maintain leadership both in aviation and space and meet many civilian and military requirements of the future.

I might just say in conclusion, we could go on and list many further examples. The real point about how we go about taking a broader view is the issue: how to eliminate excessive compartmentalization. I believe it is seeing the activities of our Government in too much a structured and compartmentalized way rather than in seeing the sweep and the relationship of activities in one sector of the Government to activities in another sector not only of Government but of the industry.

We need to realize that the $65 billion a year that Government invests in R&D has broad applications. Sometimes, like in the 707 program, that application comes naturally. On many occasions, steering signals from Government and in cooperation with industry, and in some cases the universities, can help make that much more directly relevant and also derive greater benefit for the $65 billion that industry puts into R&D each year. And before I would address subjects of additional funds for industrial research type activities, I would certainly spend a great deal of effort on seeing that the Government, both from the administration and the congressional side, is doing all it can to provide the help to make sure we are using that $65 billion we are spending today each year in R&D in a way with the most general benefit.

There are many things we can do in that regard, and we can discuss some of those in the questions, if you wish. They go all the way from standards, which are different today in our commercial and our Government sectors but, in general, need not be different, to the general financial constraints in our economy, and how, when we somehow wish to encourage savings, we take away the individual retirement accounts, the IRA programs, that when we wish to encourage long-term views by our industry we raise the long-term capital gains tax, and so on. Issues like that will certainly distort the market and distort the way our industries invest their funds.

Mr. Chairman, it is not in my testimony, but I might say, at one point in the not too distant past I was a founder and one of the owners of a company which, when it went on the market, sold for a price-to-earnings of about 20:1. We didn't have to worry about people trying to take over the company, because it was clear that that company was pointed to the future, that it had good prospects and it was well worth investing in, but the price was high, not because of what it was doing today but because it had a vision of where it was going and had a real future before it. I think our own industry would find much less trouble in the take-over area if it had a greater vision of where it was going and what its future led to, and I think there are cases in our industry where that does occur, but there are far too many when it does not.

I spent yesterday at Oak Ridge National Laboratory. They are doing some marvelous work there, and industry is being generated around that laboratory at a very high rate, and industry is cooperating with that laboratory at a very high rate. But I was told the story about four years ago where some new materials were being produced at Oak Ridge and industries that would be interested in it and were called in, and it was shown to them, and the most prevalent response that the laboratory got was—to the lab, was, "We would prefer that you, the lab, not tell many people about that, because if we had to use that new material in our industry, we would

have to retool, and rethink the way we were doing, and redesign our products, and so on, and we are very complacent and content the way we are now."

I was told by the laboratory that that view is changing rapidly in the U.S. industry, and those companies which can adapt to rapid change in the real future, I think they'll have a bright future in this country. To those industries which are complacent, which are the dinosaurs of today, I think better they go the way of the dinosaurs and that we focus our help on the aggressive, rapidly advancing industries in this country, and they, in turn, can take great advantage of the substantial investment in R&D that this country makes each year.

Thank you, Mr. Chairman. I'll be glad to address any questions you might like to pose.

[The prepared statement of Dr. Graham follows:]

PROPOSED TESTIMONY OF DR. WILLIAM R. GRAHAM
SCIENCE ADVISER TO THE PRESIDENT
AND DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY
BEFORE THE HOUSE COMMITTEE ON SCIENCE,
SPACE, AND TECHNOLOGY
APRIL 11,1989

Mr. Chairman, distinguished Members of the Committee:

I deeply appreciate this opportunity to offer testimony in support of the Committee's hearings on the subject of "Creating the New Wealth - R & D Funding in the 1990s". In keeping with the Chairman's invitation, I shall more particularly address the National Aero-Space Plane, its role in our nation's leadership in aerospace technology, and its potential future impact on our economic and national security sectors.

The science and technology policy of the Bush Administration was laid out in summary form in the President's message to Congress on "Building a Better America" dated February 9, 1989. This Administration, continuing the strongly held views of the previous Reagan Administration, believes that our future national security and well-being vitally depend on strength and progress in science and technology. I am convinced that this belief is shared by this Committee and by Congress as a whole.

As clear evidence of the Government's support, we have been increasing the federal funding for science and technology for some time, and will continue to do so, even in an era of unprecedented budget constraints. As an example, we are boosting the budget of the National Science Foundation by a factor of 2. Other essential science activities are also proposed for increasing or at least stable budget support.

So, while funding is never fully sufficient, other important factors contribute to the vigor and effectiveness of our science and technology efforts.

One of the most important is the interaction of our R&D community with their foreign counterparts, and the concomitant international aspects of technology developments and applications. We have made a lot of progress in this area, although much still remains to be done. The Organization for Economic Cooperation and Development (OECD), 24 of the largest industrialized nations of the Western alliance, have put together a framework on international cooperation in science and technology, laying down terms and conditions for cooperation on issues such as reciprocal protection of intellectual property rights. We have established the principle that basic research should be conducted by all nations in proportion to their wealth and in keeping with their state of advancement; and that results of such basic research should be made available to other nations.

We completed a science and technology cooperation agreement with Japan signed by President Reagan and Prime Minister Takeshita at the Toronto Summit in June 1988. Congress was most supportive because we made the cooperation manifestly reciprocal, balanced, and mutually beneficial. Japan also agreed to make important changes in the area of patents and other intellectual property issues. Efforts are under way for achieving similar objectives with India, Brazil, and other countries.

Just as important as the interaction with foreign nations is the effective utilization of our intellectual and physical resources within this country. We have high industrial capacity utilization, low unemployment, and stable economic growth in the country today. This is consistent with the legacy of the post-World War II era, when the U.S. was the predominant industrial base in the world. In the early days of that era, we became accustomed to uncontested economic and industrial leadership, including the institutionalized development of advanced technology.

In the late 1960s something happened; in fact, it started happening about 1945, as many of the countries of the world began to rebuild. In several instances, our financial support has helped allies and former enemies alike to modernize their production plants to compete most effectively with their U.S. counterparts.

In the late 1960s our trade balance and overall manufactured goods became negative for the first time. In 1980, our high-technology trade balance, which was very positive up to that point, suddenly began to decline; it then became negative by 1986 and has remained negative ever since.

Many causes have been ascribed to these adverse trends. In the interest of brevity, I will mention only some of them. (1) In the interest of profitability, U.S. corporations turned to off-shore manufacturing, automatically exporting manufacturing know-how and correspondingly decreasing the skilled labor base in the U.S; (2) The long-term R&D investment by U.S. industry is often eschewed in favor of near-term "bottom-line" emphasis, a situation made worse by unusually high long-term capital gains taxes; and (3) Until very recently, U.S. industry resisted collective efforts such as consortia and technology sharing, steeped as they are in more than a half a century of antitrust legislation. Our foreign competitors in Japan, Western Europe, and some emerging nations do not suffer from these adverse circumstances to the same extent.

Continuing trade deficits, especially in the areas of high technology products, have more than just economic consequences. They mean that in the long run our industry may not be in a position to support our military security or for that matter, support our foreign policy objectives by contributing to the development of strategically important emerging nations, and continuing mutually beneficial cooperation with industrialized nations.

U.S. private industry must be encouraged to increase its long-term R&D investment in a manner that would effectively contribute to the nation's future science and technology leadership, and at the same time support private corporate objectives of stability and long-term profitability.

Beyond international science and technology cooperation, and beyond the need for long-term R&D investment by the private sector, I would like to emphasize two integrating elements, absolutely vital for our future.

One is the careful nurturing of our educational base, to ensure that the next and ensuing generations will have the appropriate proportion of professional talent to support our industrial estabishment. We must have a cadre capable of doing world class scientific research; but at the same time, we must have professionals and craftsmen aimed at engineering, manufacturing, and marketing. Our elementary, secondary, and higher level educational establishments must supply the motivation and the means for fulfilling these needs. Industry, for its part, must provide the jobs and the career paths that justify individual sacrifices by those who elect science and technology careers.

Closely connected to education is the high-performance computing and computer network initiative, strongly stimulated by this distinguished Committee. An interagency report summarizing my views on the subject is in preparation. Paraphrasing the report, our goals are to ensure U.S. leadership in science, technology, product development and applications related to high-performance computing and high-capacity computer networking; and to facilitate the use of high-performance computers and high-capacity networking by the U.S. academic, government, and industrial research, development, and production communities.

The essential tie with education should be emphasized; proposals are at hand to the effect of utilizing the information processing and transfer capacity of these advanced computer networks to the benefit of research and education in a wide range of fields.

Next in my concerns is the matter of compartmentalization. Over the last 40 years the United States has had the luxury of separating and compartmentalizing its major national sectors of activity -- university, industrial/commercial and defense. While we seem to believe that such separation is part of some natural order, it is in fact a luxury and is most unusual in the world at large.

Foreign nations that have aspired to catch and surpass us industrially have had to approach these major sectors in a more integrated way. The essential point of avoiding excessive separation of these several sectors is the better utilization of public and private resources; in particular of the R & D funds available to the nation as a whole.

The total government and nongovernment R&D as a fraction of the Gross National Product of this country is about the same as other industrialized countries. It runs around 2.8 percent of the GNP. But if you look at the defense and the nondefense R&D, two countries stand out above all the rest, by about 50 percent, -- those two are Japan and West Germany.

It is more than a coincidence that Japan and West Germany are, by most accounts, two of the world's most successful countries at international trade. But this does not mean that the government expenditures in defense have no potential for commercial benefit. That idea is more an artifact of our current perspective and the compartmentalization to which we have become so accustomed.

Let me give you just one example of how military R&D contributes to our "civilian" goals. Following World War II, the B-52 bomber needed refueling by a jet tanker. The Boeing Company, betting $15 million -- 27% of its net worth -- developed the KC-135 Stratotanker at the same time it was developing its 707 aircraft. First among its competitors, Boeing was successfull and followed up with the 720, 737, and again with the 747, 757, and 767.

This aggressive approach, reaping the benefit from military developments, resulted in a world leadership position in commercial aviation, with a $75 billion backlog of orders and a net trade surplus of about $18 billion a year. The government, taxpayer, military, and industry all benefited from a number of commercial and military derivatives of that aircraft family.

In response to the Chairman's request, I would like to return for a brief moment to our leadership in aeronautics. Let no one have any doubt: technology will not stand still, and unless we vigorously pursue the technologies that will dominate air transportation in the next century, others will proudly point to their foresight and their leadership.

Thanks to the pioneering efforts of DARPA we have a major platform being established for advanced aerospace transportation in the National Aero-Space Plane (NASP) program. President Bush strongly supports this program that was introduced by President Reagan in his 1986 State of the Union address. Many Senators and Congressmen from both parties (especially the distinguished Chairman and many Members of this committee) are also on record as strong supporters.

The NASP is a highly significant longer range <u>research</u> program that will advance affordable access to space by developing a flight vehicle that can operate from a runway, and through the flight regime all the way to orbital velocity. Follow-on <u>operational</u> vehicles will complement the Space Shuttle and expendable launch vehicles, adding greatly increased capabilities while possibly reducing today's launch costs substantially.

Applications for follow-on vehicles, with the capability for flexible and affordable access to almost any point in space, will be many. NASP-derived vehicles will be used by the civil and commercial sectors for space transportation and access to space infrastructure, such as the Space Station. Military applications will change the way we do business, as space, and short notice access to it, are the ultimate high ground.

The NASP is not the Orient Express. The "Orient Express", or hypersonic civil transport, may be a follow-on vehicle to the NASP. Orient Express research, and especially development, should be funded by industry, not by the U.S. government.

The technical challenges of the NASP are many and include the engine, which must be capable of accelerating a 100,000 - 300,000 lb. vehicle up to Mach 25, and materials that must be strong, light, and able to withstand heat exceeding 3000 degrees Fahrenheit.

The NASP team comprises approximately 5000 members of the U.S. government (DOD, NASA, and national laboratories), universities, and industry led by General Dynamics, McDonnell Douglas, Rockwell, Pratt and Whitney, and Rocketdyne. The real success story of the NASP program is how the five prime contractors, competing for the airframe and engine design, have united in a Materials Consortium to pool resources and share the progress on the required materials.

Other areas for teaming, such as common subsystems, and eventually management of the X-30 program, are also being considered. We see the results of what cooperation can accomplish by watching competitors like Europe and Japan. We in government must make sure we help our nation compete, by encouraging companies to work together on large programs like NASP. It is worth recalling that antitrust laws were designed to promote competition, and to avoid restraining competition and trade.

The NASP program can provide a pattern for organizing our talents to enhance U.S. competitiveness with Japan and Europe. Past cooperation between government and industry has led to U.S. leadership in military aircraft and a very strong commercial aviation industry. New forms of cooperation among government agencies, between government and industry, and among industries will be needed if we are to retain our leadership.

For a relatively small investment by the government, the NASP is leading to considerable technological progress. Government to government relations are strong between DOD and NASA, as are government to industry relations. Industry, knowing that these high speed and single stage to orbit technologies will have both military and civil uses, has invested $500 million of industry money.

Industry considers NASP to be a vital program. Japan, Europe, and the Soviet Union all want a piece of the action and are serious competitors. Since we are in the lead, we can be selective about any cooperation. The National Aero-Space Plane program with its broad bipartisan support provides a rare opportunity to "leapfrog" our current technical capabilities, maintain leadership in both aviation and space, and meet many civil and military requirements for the future.

Another recent example is that of the supercomputers. The United States, and probably most countries if they knew it, have a small number of geniuses and organizations who can build supercomputers. The U.S. government has had the good fortune and the great sense to exercise a relatively light hand in telling these teams those geniuses what to do, but has been a good customer, and has valued and appreciated the importance of supercomputers. So now we have the CRAY I, the XMP, the YMPs, the CRAY IIs; the CRAY IIIs are now in development, and Seymour Cray is now thinking about the CRAY IV.

We didn't tell Mr. Cray how to build supercomputers, but did tell him what the government's needs were in supercomputing, computational fluid dynamics, and other fields. Jointly, the Defense Department, Department of Energy, NASA, and other agencies are providing a stable customer base for the supercomputers.

When Cray Research was starting, there was one order for the CRAY I at Los Alamos that made the difference between Cray Research succeeding or failing. Had that order not been placed, and there was a lot of institutional and bureaucractic pressure to go in a different direction at that time, we probably would have lost Cray Research and everything it has done.

It helps to be lucky, but we've got to stop counting on just being lucky, and make a greater effort to be smart as well. Not that we don't have individually smart people, but we need to be institutionally smart across the government. How can we, as the U.S. federal or state government, jointly with our industries and universities, make industrialization of advanced technology more systematic and derive the benefit from necessary and appropriate federal investment? How can we make it more productive to our industry without creating new forms of compartmentalization and institutional barriers.

Another area we should concentrate on is Electronic High Definition Display. While we are agonizing over HDTV, technologically, we are in some areas the world's leader in high definition display; but until recently, we haven't been steering it toward our industry. Now, industry is waking up and government is focusing in that area. We have an industry-government cooperation program under way, but are only beginning this process.

Nuclear power is another, with many issues in the power generation area. The people of Valdez, Alaska, are discovering that oil exploration and transportation are fraught with environmental hazards; we all know that the burning of fossil fuels adds to pollution and may contribute to long-term adverse climate changes. These are facts we have known for a long time, but now have an extreme case on our hands to remind us of the urgency of our energy problems. The Department of Energy and the Department of Defense are exploring reactors with the capability for tritium production, which supplies one of the final ingredients for nuclear weapons. At least two reactor technologies are being explored.

Included in this program is development of reactor technology that meets the President's criterion of being inherently safe, and has the potential for commercial power generation. We are beginning to think about the possible civil applications of the reactor technology as we bring them forward in the design and safety review process.

We could go on and list further examples. The real point is how to go about taking a broader view; how to eliminate excessive compartmentalization. The airplanes, electronics, nuclear reactors, all illustrate the point that if we focus on objectives too narrow, if we keep "missions" compartmentalized and isolated within a single agency, we will fail in exploiting the full tential of scientific and technical achievements.

One proposal has been made for a civilian DARPA. But I am concerned that such an organization is likely to lead to even more compartmentalization and fragmentation. With very modest steering signals, and an achievable degree of coherence and coordination, we can help programs already under way or envisioned. Timely guidance would lead to better industrial benefits from the $65-$67 billion federal R&D investment.

Before concluding my statement, I would like to call your attention to a certain number of activities, some of them well under way, some in the early stage of initiative; all of them are aimed at improving coordination and cross-fertilization among governmant agencies, private industry, and universities. Individually, the related budget requirements are minimal, but this Committee's attention and encouragement is essential to continuity and eventual success.

Standards covering both commercial and government sectors need to be revised and simplified, rather than clinging to a number of federal -- agency specific -- standards. We may take a look at Western Europe, where serious effort is under way to break down the non-tariff barriers to international trade. Let us hope that we can at least emulate some of the results in this direction.

We must derive as much benefit as possible from support of small business innovative research. This is now under way, and we are conducting a review of whether it should be modified and extended beyond 1992, its currently scheduled expiration date.

For federal science and technology coordination, we have the Federal Coordinating Council on Science, Engineering, and Technology. The Director of the Office of Science and Technology Policy chairs that group and it involves all of the R&D leaders in the federal government. We have a number of committees that are very active such as committees on biosciences, supercomputing, high-performance computing, networking, and global changes.

Going beyond the science and technology area, we have the Economic Policy Council, chaired by the President (the Chairman Pro-Tem is the Secretary of the Treasury) a Cabinet-level council that deals with economic issues. We have the Council on Competitiveness chaired by the Vice President which is being established.

Finally, let me thank you, Mr. Chairman and other members of the Committee for your steadfast support of U.S. science and technology. None of us needs to be reminded of the awesome responsibilities of the Committee. Still, progress in science and technology is exhilarating intellectually and vital for the nation's future.

The CHAIRMAN. Good. Very good.

Questions?

The gentleman from New York.

Mr. SCHEUER. Yes, thank you, Mr. Chairman.

Dr. Graham, you have also given us a great deal to think about. The FSX that is in such controversy now, do you think, on balance, our national interest is served by going into this joint venture with Japan? Will we be getting more than we will be losing in technology? Or do you think that if we give the Japanese the technology we would be giving them there is a real chance that they, you know, five, ten years from now, they would wipe us out or severely compete with us in the production of both civilian and military aircraft, as they have done in so many other industries—automobiles, computer electronics, consumer electronics, computer chips, and the like? The list is long and painful. They have shown a great capacity to take our science and do better in the manufacturing, the distribution, the sales, the promotion, and the applied science process as compared to the pure science that we seem to be very good at. How do you come down on this? Where do we maximally serve our national interest in the future of our aircraft industry on FSX?

Dr. GRAHAM. Several comments. First, I would not make a blanket condemnation of U.S. industry's lack of competitiveness or lack of ability to acquire and use new technologies. It varies a lot.

I remember a quote of a few years ago by, I think, the then chairman of General Motors when he said, "Whoever heard of a Japanese car?" That is a real problem. On the other hand, we have got companies like Hewlett Packard, Techtronics, some of our microprocessor builders who are absolutely world class and who no one can compete with. Those companies move very, very fast and are working to move even faster.

The FSX agreement is not yet complete, and therefore I can not address it as an entity because it is still being resolved between the Government of U.S. and the Government of Japan. I could make a few comments about it.

It is clear that the Japanese have an interest in industrial policy as well as defense policy associated with everything they do, including the FSX. It is also very clear, and in fact the chairman of Mitsubishi Heavy Industry has said that he sees the FSX program as providing a technology to help with advanced air transport, including hypersonic transport, such as the aerospace plane is pursuing.

Mr. SCHEUER. That is the Tokyo Express?

Dr. GRAHAM. That is the Orient Express.

Mr. SCHEUER. The Orient Express, yes.

Dr. GRAHAM. Yes. They are looking to that aircraft technology and to aircraft technology in general.

On the other hand, last year, President Reagan and Prime Minister Takeshita signed an agreement for cooperation in science and technology, and that agreement, I think, was well accepted both in the administration and the Congress, and for a very good reason; it was based explicitly and manifestly on a balance of reciprocity and a mutual benefit in technical cooperation, and that was the policy of the Reagan administration, and that is the policy of the Bush administration, and that policy, I believe, will be reflected eventually in our relationships with Japan in and across the whole range

of high technology areas, I presume including the FSX. But since the agreement is not complete I can not give you a definitive comment on that, but that is certainly our intent on that agreement and others.

In other words, we intend to give—to get at least as good as we give in these programs and to use it to raise our technology base as it is raising others.

Mr. SCHEUER. Were you here for the last witness's appraisal of the superconducting supercollider and how we should place it on our list of priorities?

Dr. GRAHAM. Yes. It reminded me a little bit of the comment—I think it was Lord Rutherford who said around the early part of this century, "Whoever talks about energy coming from nuclear processes is talking moonshine." It is probably the classical role of the conventional wisdom of the scientific community to say that new things are not going to be terribly constructive, particularly if they are major steps forward.

Mr. SCHEUER. Well, let us assume for the sake of argument that we are all keenly interested in the new technology of the superconducting supercollider. What is the best way for us to be in the ball park, be a participant, but maximize every dollar that we have invested in it so we have something left for the whole other broad range of challenges and very useful missions in the science—in the application of science? Do you come down with his feeling that we could spend that $500 million a year of interest on the $5 billion investment, and get a bigger bang for our buck across the range of science, and get most of the advantages by being a participant, or do you feel that we should go it along, as the current plan seems to be?

Dr. GRAHAM. No. I believe he had a fundamental misunderstanding on the SSC program. It is not a "go it alone" program.

Mr. SCHEUER. No. I am not talking about SST, I am talking about the superconducting supercollider.

Dr. GRAHAM. That is the SSC. That is what I meant by the SSC.

Mr. SCHEUER. Oh, SSC. Yes, right.

Dr. GRAHAM. It is fundamentally an international program. We have taken a position of leadership in that program of pulling it together, of getting it started, but we look to international participation in the use of that machine, just as there is on all high-energy accelerators, and we are looking to international participation in the construction of that machine with substantial contributions both in equipment and funding coming from other countries.

So I believe his characterization of it as a U.S.-only program was not accurate. It is inherently international in construction, in support, as well as in operation. It should be inherently international, and that is very much our intention, and I believe that is the way to make it the most productive for the U.S.

Mr. SCHEUER. One last question. Can you give us some estimate of the timetable for the Orient Express? When is it likely to be operational? And, perhaps, should we sort of try and internationalize it and get some burden sharing cranked into that process, or, from the point of view of American industry, the aircraft industry, should this be our product that we will then sell both services and the product itself to the rest of the world?

Dr. GRAHAM. I believe that if we stay on schedule with the X30, which is bringing it to a flight vehicle in the first half of the next decade, that we should have a viable hypersonic transport no later than the early part of the following decade—that is, the first decade in the twenty-first century, and there may be some intermediate steps of a commercial application in that time.

As far as the foreign involvement, again, I would go back to the more general principle which says our cooperation with other countries should be balanced, reciprocal, and mutually beneficial, and we should judge it on an issue-by-issue basis. Let's see what technologies and capabilities other countries have to bring to the table compared to what technologies we have, and make the decision on that basis.

Mr. SCHEUER. Thank you very much, Mr. Chairman.

The CHAIRMAN. Mr. Rohrabacher from California.

Mr. ROHRABACHER. Dr. Graham, could you give us a couple of examples of why the National Aerospace Plane—what it will be able to do? I am sorry, maybe you did this earlier on, and I was running in and out, but could this possibly be the—you know, we have gone through a DC3 and a 707 and a 747 as the work horses of the industry. Could this possibly be a work horse of American aerospace in the next century?

Dr. GRAHAM. The aerospace plane itself, the X30, will be entirely a research plane. It will be the X15 or the Boeing-80, that is, to say, a test vehicle, not a work horse itself. The planes derived from that—the space shuttle, the 707, and so on—will be the applications, and they, in very high likelihood, will be the work horses of the first part of the century.

Mr. ROHRABACHER. So what we are doing to invest in the national aerospace plane today is basically developing this technology that will be the, for lack of a better description, the work horse of a decade and a half or in two decades from now.

Dr. GRAHAM. Yes.

Mr. ROHRABACHER. All right. You mentioned that the Japanese and the Germans are involved in research on a national aerospace plane of their own. Is that right?

Dr. GRAHAM. They are addressing some parts of hypersonic flight, yes, but not with either the structure or the effort that we are putting into it today.

Mr. ROHRABACHER. Is it possible, if the United States withdrew from its commitment for a national aerospace plane, that the Japanese and the Germans could develop this, and we would say that two decades from now we could wake up and they would be on the cutting edge of technology, selling this craft to the world, and we would be left out of that type of market and be buying our product from the Japanese in this very important industry?

Dr. GRAHAM. Yes, I think that is a distinct likelihood.

Mr. ROHRABACHER. A distinct likelihood.

Why are some people, do you believe—I understand that there have been attempts to defund the research and the development of the national aerospace plane, or at least cut it back dramatically, in the Air Force and in the civilian area as well. What do you think the motive is behind the people who are trying to cut back on that funding?

Dr. GRAHAM. Well, the wheels of the budget process are still turning, and I do not want to prejudge those or any particular agency. But, as you can imagine as a general point, when funds for literally today's operational capabilities, facilities, and so on become very scarce, there is always a tendency, not just in Government but also in industry, to look to the longer-range accounts and to go into those for funds for current activities or more near-term activities.

Mr. ROHRABACHER. So this is another example where the United States might be—unlike Japan who tends to be taking the long-term approach—again, might be taking a short-term—some people within our Government and even within American industry are trying to make short-term profits rather than looking at the long-term picture.

Dr. GRAHAM. I would hope that that would not be the case, and certainly my view of the matter is that we can not lose sight of the long-range objectives while we are trying to deal with the present-day budgetary difficulties.

Mr. ROHRABACHER. I would like to congratulate you—take this opportunity to congratulate you on all the fine work you have been doing and all the wonderful things that you have done for the Americans who are going to live two decades from now and going to be enjoying the fruits of the commitment and effort that you put out right now. So thank you very much, sir.

Dr. GRAHAM. Thank you.

Mr. SCHEUER [presiding]. Congressman Tim Valentine.

Mr. VALENTINE. I do not have any questions, Mr. Chairman, except to express my appreciation to the Doctor for being here with us to share these words of wisdom. Thank you, sir.

Dr. GRAHAM. Thank you.

Mr. SCHEUER. Who is next over here?

Mr. SCHIFF. Mr. Chairman, in deference to time, I have no questions.

Mr. SCHEUER. All right.

Congressman Ritter of Pennsylvania.

Mr. RITTER. Thank you, Mr. Chairman, and I will try to be brief.

Welcome, Dr. Graham, again.

Rustum Roy, in his testimony—and I unfortunately excused myself for not being here for this wonderful—from what I hear, it was an excellent hearing. I was chairing a panel on Pan-Am Flight 103. The head of the parents group is in my district, and we held this panel today. But I apologize for not being here.

Rustum Roy, in his testimony, talked about the idea that somehow basic science produces technology products, and competitiveness has held sway in our Federal R&D policy over the years, and he feels that it is time to change our approach. He talked about our science-producing machine and the Japanese having a science-eating machine. And he talks about the fact that producing ever more science simply is not going to provide the competitive edge in processes and products in global markets and global competition, and that he believes that in such areas Congress must start from scratch—I am quoting—to build new policies on the solid ground of reality. And he basically talks about how industry and the work of

the industry and the collaboration of industry is really where we need to get to hit this cutting edge in the global economy.

Of course, that is quite different than what we have been doing and, to some extent, what we are proposing to continue to do. Do you have any comments on Dr. Roy's analysis and recommendations to us in the Congress?

Dr. GRAHAM. Well, I would say first that there has never been a question that science alone will not sustain the economy. On the other hand, science provides a base on which we can build new technologies if we choose to do so, if we choose to from the Government for Government purposes, if we choose to from industry from industry purposes.

We choose to do so from the Government and industry as well. In fact, each sector puts about $65 billion in R&D each year. It comes out totaling about 2.8 percent of the Gross National Product, which is about the same as all of the industrialized countries of the world, including Japan, Germany, and so on. Government is increasingly working to see that the science that it supports and the technology that it pursues in its development programs and applied research programs are made available to industry and that industry is encouraged to pick these up and implement them.

As I mentioned just before you got here, I believe, I spent yesterday at Oak Ridge National Laboratory. There is a very large-scale program of cooperation between the Department of Energy, the Martin Energy Systems Company, which is the contractor running the Oak Ridge Laboratory, and literally tens of corporations, and each year something over 2,000 guest researchers who come to the lab to do research projects, not just to kick the tires, but to really go there and work.

There are something on the order of 60 new companies that have sprung up around the lab in the last 2 years; 10 percent of the population of Oak Ridge is made up of research scientists, technicians, and support people who have come in to be employed in these new concerns. That, I believe, is a model for the efforts that we will have to make nationally in an increasing fashion.

I applaud the Department of Energy for its initiative in this and look to other departments to be equally aggressive.

Mr. RITTER. I would like to concur with you. I think that Oak Ridge has done an excellent job. But what about the criticism that the model is wrong, that instead of looking at the markets and having industry steer the overall directions of the massive Federal R&D economy at least to a far greater extent, that the money really goes into the national laboratories to a very large extent and then they look for cooperators. Then it goes into universities to a very large extent.

Rustum Roy makes the point that our global competitiveness based on technology is not going to be driven by universities, they simply do not have that kind of a talent. It always will have to be driven by the industry, and he makes the point that what we really need to do is redirect funds towards stimulated or facilitated, collaborative approaches on the part of industry where Government matches or provides just kind of seed corn and most of the money comes from industry. I guess he is really talking about getting

more from the American model over to the Japanese model. What are your comments?

Dr. GRAHAM. I think it would be far more productive and a far better use of the tax monies that we spend to focus our attention on making sure that the $65 billion a year that the Government is already spending on research and development is done in a way which simultaneously satisfies the missions of the agencies spending those funds but, in addition, provides the maximum benefit for—

Mr. RITTER. Is that really possible? I mean since the system is driven by the momentum of past obligations that these agencies have, past political constituencies that are enormous and powerful, is it, as a scientist would say, is a second order effect a lesser effect to somehow expect now marginal spin-offs to make the kind of difference that has to be made in this virtual combat that we face in the global economy with Japan, with Germany?

Dr. GRAHAM. I do not think it is a second order effect, and I will give you a few cases. Our best, strongest area of high-tech export is commercial transports. That is clearly a spin-off that you can trace back to the need for a jet tanker to fuel the B52's and the B47's. Our supercomputer strength—

Mr. RITTER. Excuse me just a second. On the jet transport, we have been going through FSX hearings both in this committee and in a subcommittee of the Commerce Committee, which I serve on, and what we are hearing now is that the relationship between military aircraft to aerospace expenditures these days for the super-high-performance item is just too far away from the commercial. And therefore FSX shared technology with the Japanese is not going to really help their commercial airline production to be competitive with us, and this is the message, in fact, that we are getting out of witnesses from the Administration.

So hasn't there been since the end of World War II some major divergence in the military spec and in the civilian spec?

Dr. GRAHAM. Well, specs is a separate area, and we need to drive military and civilian together.

Mr. RITTER. But as a symbol of the divergence of—

Dr. GRAHAM. And that is an example of an area where we should be making the Government military work more commercially applicable by having a common system of specifications rather than disjoint ones.

The chairman of Mitsubishi has made a clear statement that he sees the FSX as contributing to the commercial aircraft industry of Japan in the future, and I would not argue with him on that.

Mr. RITTER. A lot of witnesses who testified at that same table should have been as frank as you were.

But you were mentioning—in addition to aircraft, you were mentioning—

Dr. GRAHAM. Another area is supercomputers. We are in a world leadership position in supercomputers today, being strongly challenged by the Japanese, and one of our best companies is Cray Research. The whole fate of Cray literally hung on an initial order from Los Alamos for the Cray 1 at one point, and the fact that the Government, to satisfy its mission requirements—Los Alamos in this case—has supplied a constant customer base for our supercom-

puters over time has allowed our supercomputer industry, which is a very, if you will, advanced technology, very high risk industry to not only survive but to prosper. That is another way the Government can use the funds it already spends to support our industries, and I believe that can be done in many areas.

My point is that putting the steering signals into the $65 billion of R&D that we spend each year I believe to be a very first order effect. We are doing a lot now. I believe, both as an administration and as a Congress, we can do a lot better, but we need to focus on it and make sure we understand that we are not faced just with military policy or health policy or commercial policy but we are faced with national policy and these all come together.

Mr. RITTER. Thank you, Dr. Graham.

Thank you, Mr. Chairman. I yield back.

Mr. SCHEUER. Thank you, Congressman.

Dr. Graham, thank you very, very much. We have thoroughly enjoyed and benefited from your testimony.

Dr. GRAHAM. Thank you, Mr. Chairman. Thank you for your kind words.

Mr. SCHEUER. Now we will hear from Dr. Victor Peterson of the Ames Research Center of NASA, Moffett Field, California.

All right, Dr. Peterson. We are very happy to have you here. We are running a little bit behind time, so we hope that you can chat with us for about five or six minutes. I see you have a presentation to make.

[The biographical sketch of Dr. Peterson follows:]

National Aeronautics and
Space Administration

Washington, D.C.
20546

Biographical
Data

VICTOR L. PETERSON
DIRECTOR OF AEROPHYSICS
NASA AMES RESEARCH CENTER
MOFFETT FIELD, CA 94035

Mr. Victor L. Peterson joined the staff of the NASA Ames Research Center as an aeronautical research scientist in 1956. Early in his career, he conducted numerous analytical and experimental investigations of the aerodynamic behavior of supersonic aircraft configurations. This led to some of the first studies of the behavior of vehicles flying in gases other than air, including the aerodynamics and six-degree-of-freedom motions of vehicles undergoing high-speed entry into the atmospheres of planets other than earth.

After several years as Chief of the Aerodynamics Branch, Mr. Peterson was selected in 1974 to lead the Thermo- and Gas-Dynamics Division. While in that position and continuing to the present time, he has played a major role in articulating the importance of large-scale scientific computers to future developments in science and engineering. He was one of the originators of the NASA initiative to develop the Numerical Aerodynamic Simulation (NAS) System, the leading computational resource for the country's aerospace program. He continues to serve as a spokesman for that program.

In 1984, he was appointed to his present permanent position as Director of Aerophysics. Programs within the Directorate include computational and experimental fluid dynamics, high-speed aerodynamics, computational chemistry, atmosphere entry technology, computer science, automation sciences and the Numerical Aerodynamic Simulation Program. The Directorate also is responsible for managing the Center's high-speed wind tunnels, arc-jets, shock tubes, ballistic ranges and large-scale scientific computer facilities.

In 1988, Mr. Peterson was named to the position of Acting Deputy Director of the Ames Research Center, and served in that position until February 1989, at which time he returned to his permanent position as Director of Aerophysics. He continues to articulate the requirements for even more advanced supercomputer systems. He has served on many national boards and committees involved with computers, including the Technical Review Group chartered by the National Science Foundation to assist with the development and implementation of the initiative to create federally funded national supercomputer centers at several universities. Mr. Peterson has written over 45 technical papers and reports in the fields of fluid- and flight-mechanics and on the use of supercomputers in science and engineering. He was elected a Fellow of the American Institute of Aeronautics and Astronautics in 1986, and was awarded the NASA Medal for Outstanding Leadership in 1984.

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STATEMENT OF DR. VICTOR L. PETERSON, DIRECTOR OF AEROPHYSICS, AMES RESEARCH CENTER, NASA, MOFFETT FIELD, CALIFORNIA

Dr. PETERSON. Right. I will be brief in my remarks, Mr. Chairman.

Mr. SCHEUER. All right.

Dr. PETERSON. I do have three charts to show, if we could have the screen down.

Mr. SCHEUER. Good. Thanks.

Dr. PETERSON. First of all, I do welcome this opportunity to appear before you to discuss the crucial importance of supercomputers to the Nation's leadership in science and technological programs and to the national economy as well as to a strong defense posture.

Supercomputers are revolutionizing the way that scientific knowledge is acquired and applied, and while this revolution began about 25 years ago, it is still in its infancy. It is gathering momentum, however, with exponential growth, and supercomputers are becoming indispensable in nearly all areas of science and engineering.

Geologists and chemists use supercomputers; engineers use supercomputers to design fuel-efficient automobiles, ships, and aircraft, and to design more effective weapons systems; chemists use supercomputers to develop new pharmaceuticals, new catalysts for use in the petroleum industry, and new and stronger, more environment-resistant materials.

Scientists from many disciplines are using supercomputers to understand the forces that are changing the global environment, with the goal of suggesting actions to assure the continued habitability of the earth. Supercomputers are even being used in the production of motion pictures.

Now why are they important? First of all, supercomputers provide physical information and insight not accessible by any other means. For example, it is not possible to perform controlled experiments on long-range variations of global weather and climate.

Mr. SCHEUER. If the witness will yield at that point, I had a hearing on our National Hurricane Detecting Service a couple of days ago, and I was told that the British, who have a far more sophisticated and far more effective weather information service than we do, use an American supercomputer and that our National Weather Service has no such sophisticated state-of-the-art computer service available.

Dr. PETERSON. That may be true, sir. My comment was that it is possible to run these controlled experiments on the future weather and climate situation by using supercomputers, and the Europeans are doing well at that, and we probably could take a lesson from them there.

Mr. SCHEUER. And they are doing it with our supercomputer, which we have not yet made available to our National Weather Service. What an irony.

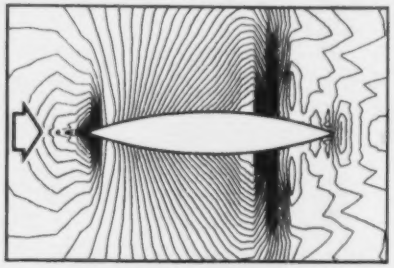
Dr. PETERSON. That is exactly right.

Each new generation of supercomputer permits larger and more complex problems to be solved, and that is the point I wanted to illustrate with these charts here.

[Charts referred to follow:]

INCREASES IN SUPERCOMPUTER POWER ENABLE ADVANCES IN COMPUTATIONAL FLUID DYNAMICS

1975

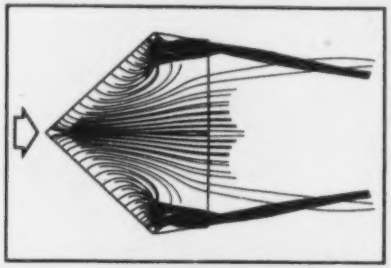


COMPUTER:
- CDC-7600

EFFECTIVE SPEED:
- 3 MFLOPS

COMPUTATION TIME:
- 5 HOURS

1983



COMPUTER:
- CRAY-1

EFFECTIVE SPEED:
- 30 MFLOPS

COMPUTATION TIME:
- 20 HOURS

1986

COMPUTER:
- CRAY-XMP/4

EFFECTIVE SPEED:
- 200 MFLOPS

COMPUTATION TIME:
- 15 HOURS

1989

COMPUTER:
- CRAY YMP/8

EFFECTIVE SPEED:
- 1000 MFLOPS

COMPUTATION TIME:
- 6 HOURS

EQUATIONS SOLVED: REYNOLDS-AVERAGED FORM OF NAVIER-STOKES EQUATIONS
1 MFLOPS = 1 MILLION FLOATING POINT CALCULATIONS PER SECOND

Figure 1

COMPUTER SPEED AND MEMORY REQUIREMENTS COMPARED WITH COMPUTER CAPABILITIES

2-hour Runs with 1988 Methods

Aerodynamics From Reynolds-Averaged Navier-Stokes Equations

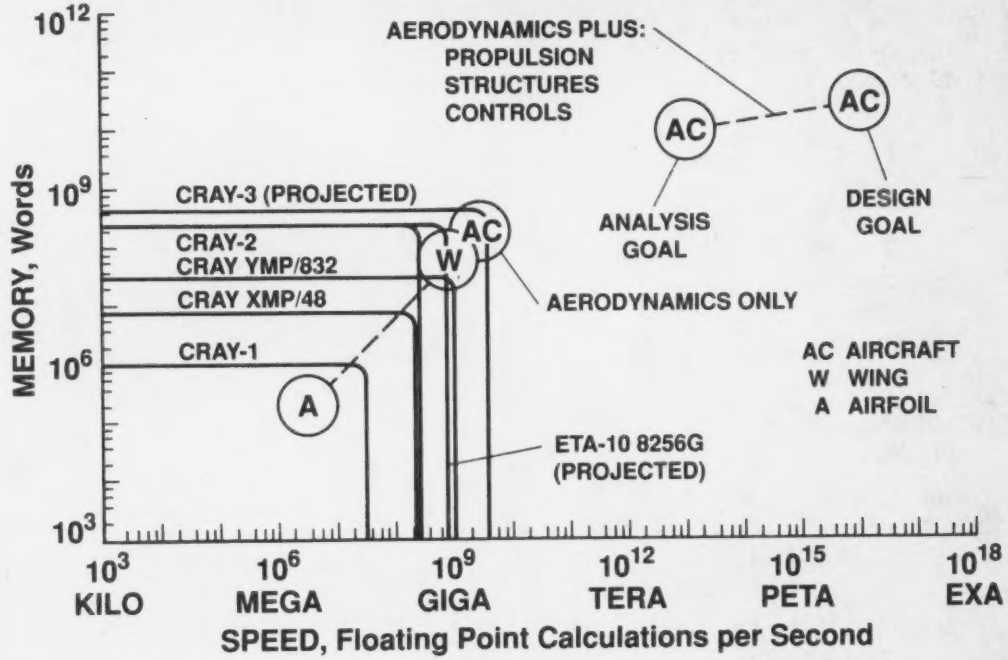


Figure 2

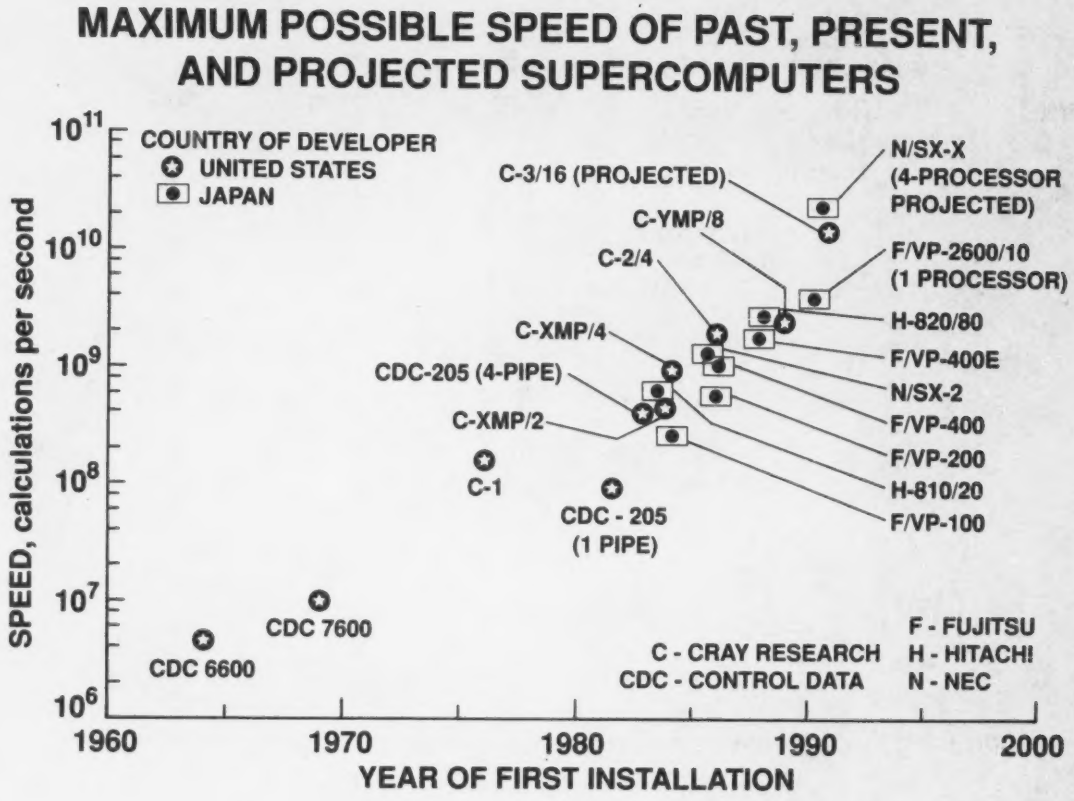

MAXIMUM POSSIBLE SPEED OF PAST, PRESENT, AND PROJECTED SUPERCOMPUTERS
SPEED, calculations per second
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
COUNTRY OF DEVELOPER
UNITED STATES
JAPAN
C-3/16 (PROJECTED)
N/SX-X (4-PROCESSOR PROJECTED)
C-YMP/8
C-2/4
F/VP-2600/10 (1 PROCESSOR)
H-820/80
C-XMP/4
F/VP-400E
CDC-205 (4-PIPE)
N/SX-2
C-XMP/2
F/VP-400
F/VP-200
C-1
H-810/20
CDC - 205 (1 PIPE)
F/VP-100
CDC 7600
CDC 6600
F - FUJITSU
C - CRAY RESEARCH
H - HITACHI
CDC - CONTROL DATA
N - NEC
1960
1970
1980
1990
2000
YEAR OF FIRST INSTALLATION

Figure 3

These charts (figs. 1,2,3,) show how improvements in computers over the past 15 years have permitted solutions to be obtained for the flow about increasingly more complex aerodynamic shapes.

Now the most widely used supercomputer in 1975 was the Control Data Corporation 7600 system, and in the upper left-hand corner of the chart you can see that, with its speed of 3 million calculations per second, we could, for the first time, make a completely viscous flow computation of the flow about a two-dimensional airfoil. That was in 1975.

Then the Cray 1 came along with its effective speed of 30 million calculations per second, and we now could take the step from two dimensions to three dimensions and do for the first time the viscous flow about a three-dimensional wing, as shown in the upper right-hand corner.

Then in 1986, the Cray XMP, in this case 48, machine with a 200 million calculations per second capability allowed us to take the next step to a relatively complete three-dimensional airplane and calculate the pressures and the flow distribution about that configuration. And, most recently, in 1989, with the new Cray YMP supercomputer, which has a capability of 1 billion calculations per second, we now can do the flow about the space shuttle launch configuration in the launch mode with the solid rocket booster motors running, and these computations are providing the type of information that is just not possible to obtain in this level of detail by any other means.

Information from these types of calculations were even used to show that the recently experienced heat shied tile damage on the STS-27 flight probably was caused by debris coming from the nose cones of the solid rocket boosters and the external tank.

Another point I wanted to make, the last point, from this chart was, you can see that there has been a tremendous increase in the capability of displaying the technology that comes out of the computer over this 15-year period. Those pictures on the top were in black and white purposely because that is the way we had to quickly display the results out of supercomputers in those days, and now we get the multi-color projections which give us much more information.

Now supercomputers are enhancing the competitiveness, particularly in the field of aerospace. We have heard some about that earlier this morning. Aerospace is a leading contributor to the favorable side of the balance of trade ledger, contributing about $18 billion positive in 1988, and a large portion of those dollars came from the world-wide sale of commercial aircraft.

CFD is credited, for example, with making the Boeing 737 300 derivative aircraft possible by showing the engineers how to install the quieter and more efficient but much larger diameter turbo-fan engines on the 737 while still keeping the interference drag within acceptable levels. CFD was also used effectively in designing the newer Boeing 757 and 767 aircraft as well as various military aircraft.

But even with successes like these, our share of the world market for commercial aircraft is declining from about 91 percent in 1969 to about 75 percent today, and one of the reasons for that is that computers are leveling the playing field in the international

technical arena and enabling countries with fewer sophisticated wind tunnel facilities to develop technically competitive commercial airplanes.

Using supercomputers is the only way that we in the aerospace business can do some things. For example, CFD was used in the design of the heat shield for the Galileo probe, which is scheduled for launch later this year to eventually enter the atmosphere of the planet Jupiter. The computations were necessary since we do not have any ground-based test facilities that can reproduce the intense environment surrounding the probe as it enters the atmosphere of Jupiter at 105,000 miles an hour.

Mr. SCHEUER. Mr. Peterson, I think your testimony is a little bit technical for this audience. I wonder whether you could summarize, because we are running way beyond time, and I apologize to you for this interruption, and I apologize to you for your having waited almost till 1 o'clock.

Dr. PETERSON. I can make the summary in just five major points.

Number one, supercomputers are revolutionizing the way that knowledge and science is acquired and applied. Each new generation of supercomputer allows us to do things that could not be done before, as evidenced by the chart on the screen.

The United States still has the lead in the supercomputing technologies, but Japan is poised to overtake us, and in my prepared testimony you will see a chart that shows that the Japanese since 1983 have been producing supercomputers that have the same level of speed as our best machines produced by the Cray and ETA and Control Data Corporations.

Finally, NASA, DOE, and NSF, and DARPA are formulating a national plan to help us share continued leadership in this important technical field.

Thank you. I would be happy to answer questions.

[The prepared statement of Dr. Peterson follows:]

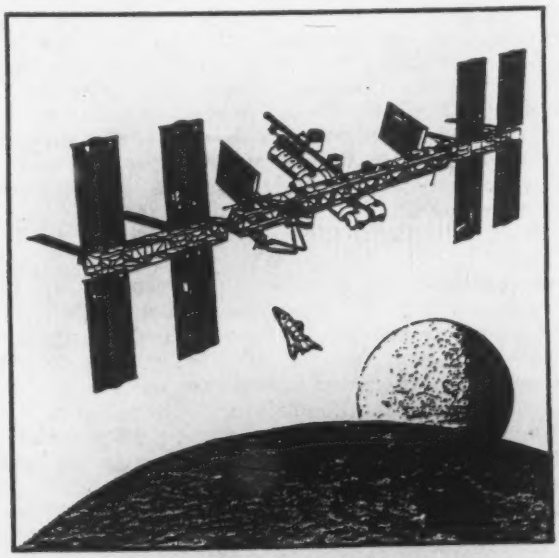
NASA
National Aeronautics and
Space Administration

**Hold for Release Until
Presented by Witness**

April 11, 1989

Committee on Science, Space and Technology

United States House of Representatives



Statement by:

MR. VICTOR L. PETERSON

**Director of Aerophysics,
Ames Research Center**

101st Congress

STATEMENT

of

MR. VICTOR L. PETERSON
Director of Aerophysics, Ames Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Committee on Science, Space and Technology
United States House of Representatives

Mr. Chairman and Members of the Committee:

I welcome this opportunity to appear before you to discuss the importance of supercomputers to the nation's leadership in scientific and technological programs, to the national economy and to a strong defense posture. The importance of computers to science and engineering can be appreciated by recalling that nearly all physical phenomena can be represented with various degrees of precision by mathematical equations and, of course, computers can solve equations. Since a supercomputer is the most powerful computing engine that has been assembled at any point in time, it can solve problems that are larger and more complex than can be tackled with personal computers or larger computer systems that are more commonly used in all walks of life. Supercomputer capability is essential to NASA's research and development programs and an integral part of the research and technology program of the Office of Aeronautics and Space Technology.

Supercomputer power is usually measured by speed in doing arithmetic calculations and by high-speed memory capacity. Each new generation of supercomputer has greater power, enables larger and more complex problems to be solved, and displaces its predecessors from the supercomputer ranks. One of today's supercomputers can perform the work of about ten thousand top-of-the-line personal computers. The speed of the most powerful computers has been increasing by a factor of about 10 in each 8 year period for the past 32 years. The ability to use this power depends on surrounding the supercomputer with necessary system components such as mass storage, intermediate size computers, high-performance workstations and high-bandwidth networks.

The recently introduced Cray-YMP supercomputer has demonstrated a sustained computational rate of over one billion calculations per second on a mix of problems, and a peak speed of about 1.6 billion calculations per second on a single problem. This sustained computational speed on a mixture of different problems is about 30,000 times greater than that provided by the IBM 704 which was introduced in the mid-1950s. While this is impressive, problems already have been identified that could be addressed today if we had supercomputers one million times faster than the Cray-YMP.

Supercomputers are a key technology for the country's future competitiveness, for national security, and for the understanding of the problems caused by humankind's impact on global environment. Although the government does not develop supercomputers, the government does support the development of enabling technologies and is an early first customer of advanced supercomputer systems. Consequently, the government has stimulated the development of supercomputing technology. Supercomputers are revolutionizing the way that scientific knowledge is acquired and applied. This revolution began about 25 years ago and it is still in its infancy. It is gathering momentum with exponential growth.

Today's supercomputers are used by scientists and engineers in a variety of technical applications. Geologists and chemists use supercomputers to enhance the search for and recovery of natural resources. Engineers use supercomputers to design fuel efficient automobiles, ships and aircraft, and to design more effective weapons systems for national defense. Chemists are using supercomputers to determine the fundamental properties of matter for use in the design of new pharmaceuticals to combat disease, new catalysts for use in the chemical and petroleum industries, and new materials for use in manufacturing and for protecting spacecraft against the severe environments to which they are exposed. Scientists from many disciplines are using supercomputers to understand the interrelationships between the naturally occurring biological and inorganic processes in the global environment and those that are introduced by the presence of people and machines. Meteorologists and atmospheric scientists are using supercomputers to provide long-range forecasts of the weather and climate changes. Astronomers and astrophysicists are using supercomputers to understand the origin and evolution of the universe. Supercomputers are even being used in the production of motion pictures.

Supercomputers can provide information and physical insights not accessible by any other means. For example, it is not possible to perform controlled physical experiments with long range variations of global weather and climate. Supercomputers offer a way to perform the necessary experiments numerically for essentially unlimited numbers of scenarios without actually impacting the environment. In fact, experimentation of this kind is already being done on a limited basis. One example is the numerical modeling of the Los Angeles Basin pollution problems for the purpose of identifying potential solutions. Supercomputers clearly complement analytical analysis and physical observation. They have, in fact, assumed equality with the more traditional mathematical theory and physical observation to become the third major tool for extending the frontiers of science and engineering.

While the mathematical equations governing many of the physical processes mentioned above are known, lack of sufficient computer power oftentimes forces the scientist to make simplifying approximations to reduce complexity to manageable proportions. However, the number of simplifying approximations can be reduced and the complexity of problems being tackled can be increased as each new generation of supercomputer is introduced. This can be

illustrated by considering one of the aerospace disciplines called computational fluid dynamics. Computational fluid dynamics, or CFD, has been designated as one of 22 technologies critical to national security by the Departments of Defense and Energy. It is also critical to continued international competitiveness in commercial aviation. Computational fluid dynamics involves the use of supercomputers to solve mathematical equations that describe the behavior of fluid flows about aerospace vehicles and/or their components. These equations have been known for many years but they are far too complex to solve in their complete form, even with today's supercomputers. Even so, certain approximations can be made to permit solutions to be obtained for realistic problems. With increased computer power comes a decreased reliance on physical modeling and, thus, reduced uncertainty in the numerically obtained answers.

Computed results shown in Figure 1 illustrate how improvements in computers have increased the capability of computational fluid dynamics over the past 15 years. The first solutions for the flow about a two-dimensional airfoil, which fully accounted for the coupling between the viscous inner flow near the airfoil surface and the inviscid outer flow some distance away from the airfoil, were obtained in 1974. The results were obtained on a leading supercomputer of that day, the Control Data Corporation CDC 7600. The problem required about 5 hours of computation and the results, such as contours of constant pressure shown in the figure, were presented to the scientist using state-of-the-art black and white display technology. In 1983, the increase in computational power provided by the Cray-1 permitted the move from two-dimensions to three-dimensions and the first fully-coupled viscous flow solutions for the flow about a wing were obtained in about 20 hours of computation. Technology for displaying the results, in this case flow streamlines, also improved but color still was not routinely available.

Further improvements in supercomputer power enabled the problem complexity to be increased so that the first solutions for the flow about a relatively complete aircraft could be obtained in 1986 with the expenditure of 15 hours of computing time using a Cray-XMP supercomputer. Further improvements in display technology permitted the image of the aircraft and its surrounding flow to be viewed from all angles and in color with minimal effort by the scientist. Now, in 1989 using the Cray-YMP supercomputer in NASA's Numerical Aerodynamic Simulation (NAS) system, problems as complex as determining the aerodynamic loads on the full Space Shuttle launch configuration, including influence of engine exhaust plumes, can be solved with about 6 hours of computation. Calculated pressures on the aerodynamic surfaces, such as those shown for the Space Shuttle, are providing information on aerodynamic loads during launch and staging of the solid rocket boosters and external tank that is far more detailed than can be obtained either in wind-tunnel or in flight tests. This kind of information is needed for better defining the permissible flight envelope during possible abort maneuvers. The computed flow fields even were used to show that the heat shield tile

damage experienced during the recent flight of STS-27 probably was caused by debris emanating from the nose cones of the external tank and solid rocket motors during the launch. Improvements in display technology permit color motion pictures to be made of the time-dependent loads on the vehicle components during staging.

CFD is helping to maintain a competitive posture in the commercial aircraft business. A good example of this was the use of CFD by the Boeing Commercial Airplane Company to revolutionize the approach to installing wing-mounted turbofan nacelles on transport aircraft. Over 20 years of previous experience based on wind tunnel tests had been used to define the minimum clearances that had to be observed between a nacelle and a wing to keep interference drag within acceptable levels. Adherence to these minimums would have prevented the installation of quieter and more fuel-efficient larger-diameter turbofan engines selected for the 737-300 derivative of the Boeing 737 airplane. A computational study aimed at understanding this problem revealed the source of the interference drag and suggested ways to contour the nacelle and strut to achieve an acceptable level of drag. This work is credited with making the Boeing 737-300 derivative aircraft possible. The Europeans also have used CFD extensively in the design of their family of Airbus aircraft.

CFD is providing aerospace vehicle designers with information not available from any other source. A good example relates to the design of the heat shield for the Galileo Probe that is scheduled to be launched from the Space Shuttle later this year. The environment that will be experienced by the Galileo Probe when it enters the atmosphere of Jupiter at a speed of about 105 thousand miles per hour, or about 6 times the speed of the Space Shuttle reentering the earth's atmosphere, cannot be created in ground-based test facilities. Computer codes were developed to simulate the intense environment surrounding the probe and the performance of the heat shield in protecting the probe against the environment. The code was validated for ranges of conditions that could be reproduced in the laboratory and then used to provide the needed information. CFD is also an enabling technology in the National Aerospace Plane Program because appropriate ground-based test facilities do not exist.

CFD is also used extensively in the design of military aircraft, missiles, submarines, and ordnance. It provides a tool for rapidly evaluating new and radical ideas for future military systems.

Further improvements in supercomputers will reduce the time required to obtain solutions and will permit several disciplines such as fluid dynamics, chemistry, structures, electromagnetics, propulsion and controls to be treated simultaneously in the design environment. A perspective on the relationship between computer power and the various capabilities that it enables is shown in Figure 2. Computer speed and memory requirements for solving problems in aerodynamics with increasing physical and geometrical complexity are

compared with several existing and planned computers. Computers having sustained computational speed of one trillion calculations per second should be available before the turn of the century. These will enable numerical simulations to drive the multidisciplinary analysis and design of aircraft and spacecraft of the future.

Aerospace is the leading contributor to the favorable side of the balance of trade ledger contributing about $17.8 billion dollars in 1988. A large portion of those dollars came from the worldwide sale of commercial aircraft. Prior to 1969 this country commanded 91% of the world market share for commercial jet transports. During the years from 1970 to 1979 this share was reduced to 84%. The share was further reduced to 75% over the years from 1980 to 1988. In the earlier years, before the advent of supercomputers, aircraft designs were based on highly simplified forms of the governing mathematical equations that could be solved without large computers and on extensive tests in wind tunnels. The early lead in aircraft technology was, in fact, largely due to the fact that no other country had as many wind tunnels spanning the necessary ranges of test capabilities. Now the situation is changing. Other countries are building new wind tunnels, but more importantly, supercomputers and the CFD technology are both becoming more widely available. Unlike a wind tunnel that takes years to construct and that has a certain limited and fixed ranges of test variables such as Mach Number, Reynolds number and flow energy, a single readily acquired supercomputer can solve the equations governing flows across the flight spectrum. Computers, and the related technologies necessary to make them useful in science and engineering, have the potential for leveling the playing field across the international arena. For this reason, it is crucial for this country to make the necessary investments in these technologies to retain the world leadership position. Of course, the test facilities still will be required long into the future. As long as approximate forms of the governing equations must be solved, the CFD codes must be validated over at least a limited range of the important variables. Computers and physical experiments complement each other. Used together they can extend the technological frontiers far more and much faster than the use of either alone.

Examples like the one presented for CFD exist for many other technical disciplines. However, differing complexities in the underlying physics of the various disciplines place different requirements on the power that a computer must have to solve the governing equations in a reasonable amount of time. Thus, each discipline has a threshold of computer power that must be exceeded before the computer becomes an effective tool in that discipline. Research and applications in the disciplines for which this threshold has been crossed, such as fluid dynamics, aerodynamics, aerothermodynamics, chemistry, atmospheric sciences, biology, astronomy, astrophysics and nuclear physics, now are as dependent on the computer as they are upon physical observation and testing. In fact, many of the experiments in these disciplines are defined by computations.

The United States still has a lead in the computational technologies for several reasons. The most powerful widely available supercomputers are manufactured in this country, and the numbers of supercomputer installations and trained computational scientists in this country's government research laboratories, industrial sites, and major universities exceed those found in any other single country. This lead will be difficult to maintain, especially since Japan is poised to overtake the United States in the design of more powerful supercomputers. In fact, Japan entered the supercomputer field in 1983. The data in Figure 3 show that since their entry the growth in maximum possible speeds of Japanese supercomputer systems has kept pace with those manufactured by the United States. Only the greater access to U. S. machines by the leading computational scientists has permitted our share of the world supercomputer market to remain relatively high since that time. This access has allowed software for the U. S. machines to become more mature so that greater fractions of the maximum possible speeds of the machines can be obtained on a sustained basis for a mixture of different computer codes. Japan and other countries also are rapidly expanding their involvement in the computational approach to science and engineering.

More than just powerful supercomputers are needed to advance the computational sciences. High-capacity and rapid access storage systems are needed to hold the massive amounts of data generated by the supercomputers; intermediate size computers are needed to free the supercomputers from doing more routine pre- and post-processing of results; high-performance workstations are required to provide the scientists a means for interacting with the system; and all of the elements of the system must be connected with high-bandwidth data networks. Supercomputer systems, like freeways, can become saturated and extremely slow if the volume of users exceeds that for which the system is capable of handling. Thus, it is important for us to realize that as the number of trained supercomputer users increases both the number of systems and the capability of each system must be increased.

The Department of Energy and one of its predecessors, the Atomic Energy Commission, recognized the importance of computers to their mission a number of years ago and they contributed heavily in the early years to the development and use of supercomputers for the design of nuclear weapons. NASA recognized the future importance of supercomputers to aerospace in the mid-1970s and they successfully advocated the development of the Numerical Aerodynamic Simulation system which, in the past 2 years, has become one of the premier supercomputing facilities in the world. The National Science Foundation recognized the importance of supercomputers to the nation's scientific endeavors and they sponsored the development of new supercomputer centers at five major universities in the 1980s. These university centers are needed to perform the extremely important task of training new scientists in the computational sciences. Through these kinds of programs, the government has stimulated the development of the supercomputing technologies.

More recently, in November 1987, the Office of Science and Technology Policy issued a report entitled, "A Research and Development Strategy for High Performance Computing," proposing a new multi-agency government program aimed at accelerating the pace of development of the computational sciences. Selected "Grand Challenges" in science and engineering were identified whose solution would be enabled by improvements in computer power and related national infrastructure. NASA, DOE, NSF and DARPA are currently taking the lead in formulating a national plan to implement the recommendations in the OSTP report.

In summary, supercomputers have become equally important as theory and physical experimentation in the fields of science and engineering. They are becoming indispensable in some technical disciplines. In fact, even though the computational sciences are still in their infancy, there are already examples in aerospace for which supercomputers have been used to enhance international competitiveness and national security. The U. S. lead in the computational sciences is being challenged as many other countries increase their development and use of computational tools, and the United States monopoly in producing the most powerful supercomputers is being challenged by the Japanese. More powerful supercomputers will be a key element in the continuing development of the technologies critical to this country's future.

Thank you, Mr. Chairman, for the opportunity to present these views on the importance of supercomputers.

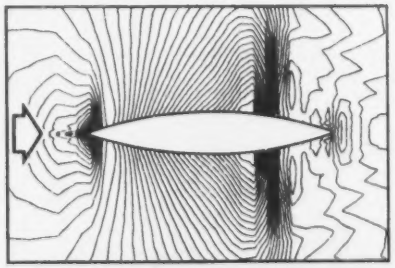
INCREASES IN SUPERCOMPUTER POWER ENABLE ADVANCES IN COMPUTATIONAL FLUID DYNAMICS

1975

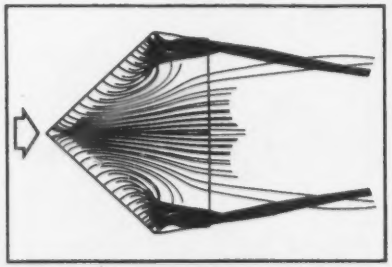
COMPUTER:
- CDC-7600

EFFECTIVE SPEED:
- 3 MFLOPS

COMPUTATION TIME:
- 5 HOURS



1983



COMPUTER:
- CRAY-1

EFFECTIVE SPEED:
- 30 MFLOPS

COMPUTATION TIME:
- 20 HOURS

1986

COMPUTER:
- CRAY-XMP/4

EFFECTIVE SPEED:
- 200 MFLOPS

COMPUTATION TIME:
- 15 HOURS

1989

COMPUTER:
- CRAY YMP/8

EFFECTIVE SPEED:
- 1000 MFLOPS

COMPUTATION TIME:
- 6 HOURS

EQUATIONS SOLVED: REYNOLDS-AVERAGED FORM OF NAVIER-STOKES EQUATIONS
1 MFLOPS = 1 MILLION FLOATING POINT CALCULATIONS PER SECOND

Figure 1

COMPUTER SPEED AND MEMORY REQUIREMENTS COMPARED WITH COMPUTER CAPABILITIES

2-hour Runs with 1988 Methods

Aerodynamics From Reynolds-Averaged Navier-Stokes Equations

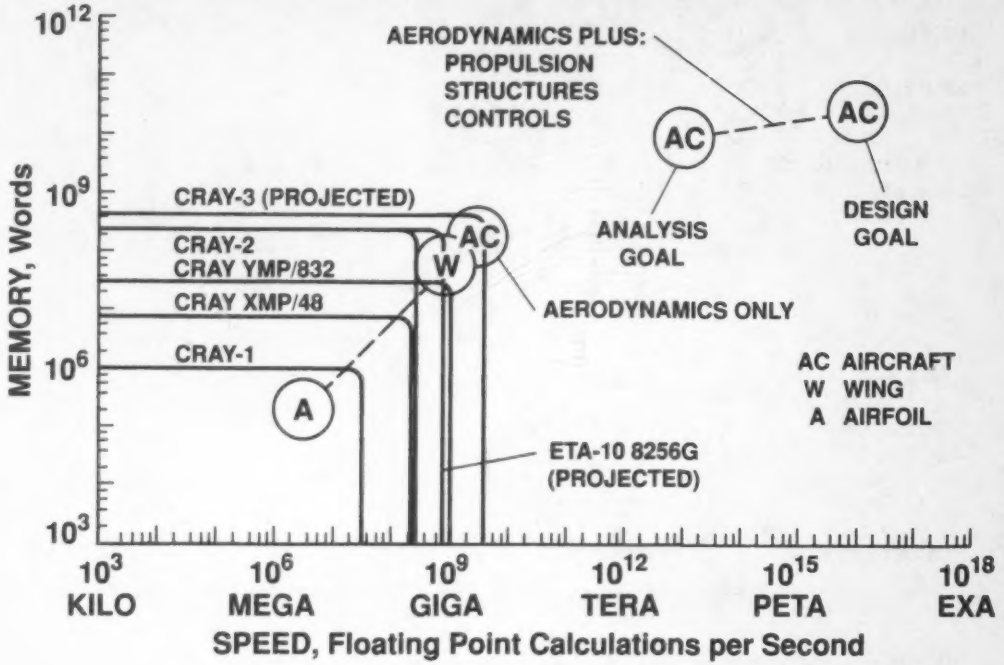


Figure 2

MAXIMUM POSSIBLE SPEED OF PAST, PRESENT, AND PROJECTED SUPERCOMPUTERS

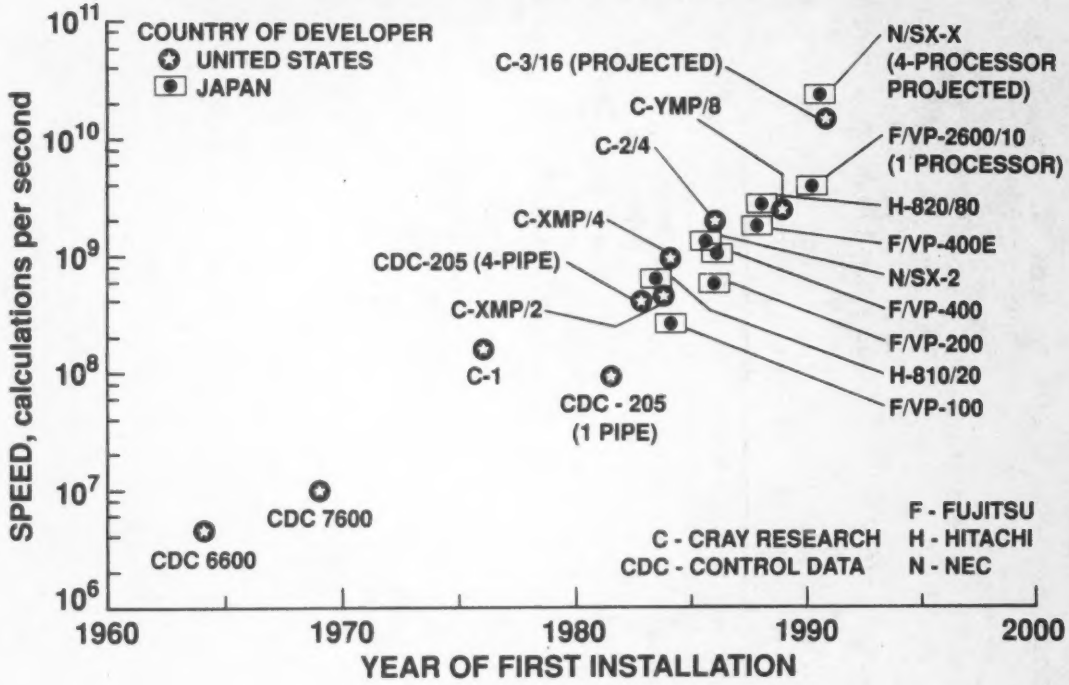


Figure 3

Mr. SCHEUER. Thank you very much, Dr. Peterson.

Congressman Ritter.

Mr. RITTER. Yes. Just briefly, we have been reading in the newspapers the last couple of days about the NEC supercomputer venture for 20 billion calculations a second—

Dr. PETERSON. Twenty-two.

Mr. RITTER. I guess Honeywell is also involved in that to a certain extent.

What is the extent of Honeywell's involvement in that project, as you see it?

Dr. PETERSON. I am not privy to all of the relationships between those corporations, but Honeywell, of course, is trying to market the systems in this country, and one of the major contributions that Honeywell would be making to that venture would be to provide a U.S.-based marketing force.

Mr. RITTER. Does that scare you? You know, here we are, we are thinking, well, we have one lead, one last bastion of U.S. technological superiority that is in advanced computing. Does it scare you that, all of a sudden, this last bastion is now under assault?

Dr. PETERSON. Well, yes, it bothers me, and the question is what to do about it.

The reason it bothers me is because I firmly believe that supercomputers are a way to the future, one of the ways to the future, and if we are at the mercy of another country who has the capability to produce a greater, faster supercomputer, then they can also determine when they want to sell it to us.

Mr. RITTER. I can accommodate the fact that, you know, we got beat in automobiles and televisions, but supercomputers—I mean, I picked this up the other day, and I just could not believe that, according to the press reports, in any event, we may be in danger of losing the lead in supercomputers. What do we need to do about it?

Dr. PETERSON. Well, one of the things we have done in the past as a Government has been to be an eager first customer of the supercomputers coming out of the U.S. manufacturing capability, and I think Dr. Graham mentioned that the Government standing by to buy the first Cray 1 was what basically allowed Cray to proceed and become a reasonably strong company. I think we have to continue to do that.

Another thing we have to do is, we have to continue to support, as the Government, to support the infrastructure that makes up computing, and that is networking software development, the supercomputers themselves, and the education, training people how to use these things. And there are some programs coming along to enhance that building of this infrastructure.

But I am concerned that the Japanese, in the machine that you mentioned there, has a top speed of 22 gigaflops. The next Cray, the Cray 3, will have 16 gigaflop top speed.

Mr. RITTER. Which comes on line first? Which gets sold first?

Dr. PETERSON. About the same time.

Mr. RITTER. About the same time.

Dr. PETERSON. Now the fortunate thing is that, since there are more U.S. supercomputers in the world market, more of the software that is available to use on these machines is tuned to machines of more of the architecture of the Cray than they are the

NEC machine, and therefore we can actually get more sustained performance out of a U.S. machine with slightly less peak performance, but that won't last for long.

Mr. RITTER. Exactly.

The irony is, too, that this was another one of those markets targeted, working with a consortia of Japanese companies. We have seen this for the first time, right? We are surprised. And the market was protected. It was early on like pulling teeth to get Crays sold in Japan, even though there was no competitor machine. Interesting.

I yield back, Mr. Chairman.

Mr. SCHEUER. Another irony is that the British bought a Cray for their weather service that is now state of the art, outcompeted us from hell to breakfast, while our Government has failed so far to purchase either a Cray or any other competing sophisticated computer for our National Weather Service or for Government throughout the length and breadth of our Government, that I know of.

Congressman Tim Valentine.

Mr. VALENTINE. I do not have any questions, Mr. Chairman.

Mr. SCHEUER. Congressman Norman Mineta.

Mr. MINETA. Thank you very much, Mr. Chairman.

I just want to thank Mr. Peterson for his leadership at Ames and the fact that we have the NAS there and the fact that DOE has—you know, a lot of this progress would not have been made possible or we would not be where we are today if it had not been for DOE or NASA taking the lead.

We had the testimony the other day of Assistant Secretary Sykes of the Department of Commerce when we were talking about HDTV, and he said, "I do not think the Government should be ahead of the private sector in terms of doing different things." Well, if we took that mentality, we would still be working with the abacus or whatever instead of working in terms of supercomputers and the real need, and your paper is a very, very fine analysis of where we have been and what our needs are in the future, and now the question is for all of us to put our heads together to see how we can come up with the resources and the programs to do these—to take a look at these things that you have outlined in your paper and your testimony, and, again, Mr. Peterson, thank you very, very much for your presence here today.

Thank you, Mr. Chairman.

Mr. SCHEUER. Dr. Peterson, thank you very, very much. We very much appreciate your testimony.

Dr. PETERSON. Thank you.

Mr. SCHEUER. And now we will hear from the last witness, Dr. Leon Lederman, director of the Fermi National Accelerator Laboratory and winner of the 1988 Nobel Prize in physics, from Batavia, Illinois.

We are delighted to have you, Dr. Lederman. Please take such time as you may need.

[The biographical sketch of Dr. Lederman follows:]

LEON M. LEDERMAN

Biography

New York City in the period of 1922 to 1979 provided the streets, schools, entertainment, culture and ethnic diversity for many future scientists. I was born in New York on July 15, 1922 of immigrant parents. My father, Morris, operated a hand laundry and venerated learning. Brother Paul, six years older, was a tinkerer of unusual skill. I started my schooling in 1927 at PS 92 on Broadway and 95th Street and received my Ph.D. in 1951 about one mile north, at Columbia University. In between there were neighborhood junior and senior high schools and the City College of New York. There I majored in chemistry but fell under the influence of such future physicists as Isaac Halpern and my high school friend, Martin J. Klein. I graduated in 1943 and proceeded promptly to spend three years in the U.S. Army where I rose to the rank of 2nd Lieutenant in the Signal Corps. In September of 1946 I entered the Graduate School of Physics at Columbia, chaired by I. I. Rabi.

The Columbia Physics Department was constructing a 385 MeV Synchrocyclotron at their NEVIS Laboratory, located in Irvington-on-the Hudson, New York. Construction was aided by the Office of Naval Research and "NEVIS" eventually proved to be an extremely productive laboratory as judged by physics results and students produced.

I joined that project in 1948 and worked with Professor Eugene T. Booth, the director of the cyclotron project. My thesis assignment was to build a Wilson Cloud Chamber. Rabi invited many experts to Columbia to assist the novice staff in what was for Columbia, a totally new field. Gilberto Bernardini came from Rome and John Tinlot came from Rossi's group at MIT. Somewhat later, Jack Steinberger was recruited from Berkeley. After receiving my Ph.D. in 1951 I was invited to stay on, which I did, for the next 28 years. Much of my early work on pions was carried out with Tinlot and Bernardini.

In 1958 I was promoted to Professor and took my first sabbatical at CERN where I organized a group to do the "g-2" experiment. This CERN program would continue for about 19 years and involve many CERN physicists (Picasso, Farley, Charpak, Sens, Zichichi, etc.). It was also the initiation of several collaborations in CERN research which continued through the mid-70's.

I became Director of the Nevis Labs in 1961 and held this position until 1978. I have been a guest scientist at many labs but did the bulk of my research at Nevis, Brookhaven, CERN and Fermilab. During my academic career at Columbia (1951-1979) I have had 50 Ph.D. students, 14 are professors of physics, one is a university president and the rest with few exceptions, are physicists at national labs, in government or in industry. None, to my knowledge, is in jail. In 1979 I became Director

of the Fermi National Accelerator Laboratory where I supervised the construction and utilization of the first superconducting synchrotron, now the highest energy accelerator in the world.

I have three children with my first wife, Florence Gordon. Daughter Rena is an anthropologist, son Jesse is an investment banker and daughter Rachel a lawyer. I now live with my second wife Ellen at the Fermilab Laboratory in Batavia, Illinois where we keep horses for riding and chickens for eggs. I have been increasingly involved in development via scientific collaboration with Latin America, with science education for gifted children and with public understanding of science. I helped to found and am on the Board of Trustees of the Illinois Mathematics and Science Academy, a three year residence public school for gifted children in the State of Illinois.

Honors

Leon Lederman is the recipient of fellowships from the Ford, Guggenheim, Ernest Kepton Adams and National Science Foundations. He is a founding member of the High Energy Physics Advisory Panel (to AEC, DOE) and the International Committee on Future Accelerators. He has received the National Medal of Science (1965) and the Wolf Prize for Physics (1982) among many other awards.

Honorary DSc's have been awarded to Leon M. Lederman by City College of New York, University of Chicago, Illinois Institute of Technology, Northern Illinois University, Lake Forest College and Carnegie Mellon University.

Leon Lederman is the recipient of the Nobel Prize in Physics in December 1988. In February 1989 Governor Thompson appointed Leon Lederman as the State of Illinois First Science Advisor.

STATEMENT OF DR. LEON M. LEDERMAN, DIRECTOR, FERMI NATIONAL ACCELERATOR LABORATORY, 1988 NOBEL LAUREATE IN PHYSICS, BATAVIA, ILLINOIS

Dr. LEDERMAN. Thank you.

I got up at 5 in the morning to try to get to this hearing on time.

Mr. SCHEUER. We appreciate very much.

Dr. LEDERMAN. And TWA was not cooperative, so I just landed, and I admire your staying power here.

Today's headlines carry two messages for us in these hearings, I think. One is the oil spill, the tragic oil spill, off Alaska; the other is the excited reports of a breakthrough in fusion research, cold fusion. While I am personally skeptical of this, it does illustrate the potential for surprise that scientific research always holds forth.

Mr. SCHEUER. Excuse me, Dr. Lederman. Would you pull that mike forward and sort of direct it toward—

Dr. LEDERMAN. Okay.

Mr. SCHEUER. Speak right into it.

Dr. LEDERMAN. The oil spill is the other side of the technology coin, the dangers and interconnectivity of a shrinking globe that a ship captain off the coast of Alaska can presumably have one too many and the price of gasoline jumps in New Jersey.

Mr. SCHEUER. Apparently he had a lot too many, not just one.

Dr. LEDERMAN. Probably.

A student in Chicago who is asked to locate the Black Sea responds, "It is off the coast of Alaska," and he is marked correct.

To address the question raised today about new wealth, let us review, and let me say that the Swedish Academy has made me an expert in all subjects—I mean Brazilian debt, Social Security, you name it, so I will proceed with history and economics.

Our Nation was clearly a world leader, and what was it? It started with a huge natural wealth in our glorious forests, abundance of coal, oil, high-grade metallic ores, a rich soil, a varied and benign climate, ample supply of clean water, and wild rivers, and great lakes. It profited from an amazing and beneficial immigration, wave after wave, each one bringing in talent which seemed almost designed to contribute in its time, from the pioneers with their courage and their vision all the way to the current contributors to the melting pot, the Asians, who have replaced Jews as the academic superstars in our graduate schools.

I include here also those who gave us our stable and flexible democracy, who installed compulsory education, land grant colleges, whose vision and statesmanship increased our wealth with the Louisiana Purchase and the Alaska Purchase, and then the waves of European scientists who fled Europe in World War II and changed U.S. science from barely respectable to absolutely dominant.

In the golden age, which I will identify as 1948 to 1968, U.S. science, U.S. technology and ingenuity, products, autos, tires, electronics, quality steels, consumer goods, machine tools, science, and science journals, and our universities were all dominant. American English was the language of choice in scientific communication, so a Japanese talking to a Yugoslav would talk in English.

Then something happened, and that happened after 1968 roughly, a decline in the U.S. spirit of innovation; students turned away

from hard subjects; we endured the slide of the seventies and began to lose our momentum in science and science education that was fired by World War II victory and refired by Sputnik.

Then there emerged the competition, which I am sure you have heard about. Other nations forged ahead. Then came this loss of technological self-confidence, witnessing things like TMI and the Challenger and our loss of high-tech balance of payments. Industry seemed to give up good research labs in favor of a search for good-looking third quarter profit sheets. And then there was the appearance of the shortages, the oil crisis, fossil fuels, and I can cheer you up with a lot of things that I am sure you all know about, which I will skip.

Anyone with a little imagination can make up a new list of crises even more frightening than the ones that we already know about, global crises of various kinds, which we have not yet encounter that no doubt we will encounter as we enter the twenty-first century.

So, what do we do? How do we replace the wealth we have depleted? How do we buy insurance against present and as yet unimagined future threats, and how do we cope with the prospects of six billion people on this planet in the next few decades and with the fact that the present situation, the shortages, the threats to the environment, were brought about by the pleasure of something like 20 to 30 percent of the planet's population having the good life, leaving the remaining 70 to 80 percent in the nondeveloped world to watch us on television?

I think you in this committee know the answer. We have to continue to invest in science and engineering and in the people who become scientists and engineers. It is only in science that you can find returns on investment that can be 10 to 1 or 100 to 1 or 1,000 to 1 and even higher, and we have anecdote after anecdote to list these examples.

The eminent economist Edwin Mansfield from the Wharton School has an ongoing study of returns on investments, and in a preliminary report I have seen he has calculated the returns on investments in academic research at a level of something like greater than 30 percent, which means that you get a pay-back in something like three years, and his estimate is very conservative.

I think the number one policy lesson is that nothing, absolutely nothing, will have a greater impact on the creation of new wealth than the enticement into science and technology of the best brains our Nation can produce, and these brains must be furnished with an environment of optimism and purpose and with the tools, the science funds, that will buy the new equivalent of the shovels and drills and TNT there were needed to dig up the old wealth.

We have a very lively and vibrant science today to build upon. Part of this was due to the foundation developed in the golden age, in the 20-year period from 1948 to 1968, and part of it is due to the increases in funding that have appeared over the last decade.

I do not have an easy answer to the question of recruitment. It involves lots of complicated things: science, education, a vastly greater public understanding and appreciation of science, probably not dominantly Federal funding but leveraged funding. But it is

clear that science, by itself, and whatever educational ideas seem relevant, that seems to be crucial.

In earlier testimony before Madam Lloyd's subcommittee, I pointed out that President Reagan, in 1980, decided to double the military budget to $300 billion. Although this has clearly created some problems, the Nation seems to have survived, and I point out that we have a $10 billion research budget that, if we double, this will also cause the Nation to survive and might even be the best investment that we can possibly provide to dig out the new wealth which is essential as a ticket to the twenty-first century.

I think I'll stop here.

[The prepared statement of Dr. Lederman follows:]

Testimony
Committee on Science, Space and Technology
April 11, 1989
Leon M. Lederman
Director, Fermilab

Mr. Chairman, I'm pleased to be invited to address the vital issue of "creating new wealth."

Today's headlines carry two messages for us in these hearings: one is the oil spill off Alaska - the other is the excited reports of a breakthrough in fusion research, i.e. cold fusion. Although I am very skeptical of this, it does illustrate the potential for surprise that scientific research always holds forth. The oil spill is the other side of the technology coin, the dangers and the interconnectivity of our shrinking globe, that a ship captain off the coast of Alaska can have one-too-many and the price of gasoline jumps in New Jersey - and a student in Chicago, asked to locate the Black Sea, responds: near Alaska and is marked "Correct."

To address the question raised here today, my background and experience compels me to take the long view. Also, although you'll find it hard to believe, I am a grandfather and I am concerned about what kind of a world my grandchild and his friends will face. At age 15 he will be allowed to stay up late to witness the arrival of the 21st century. Now how will this compare with our century - the 20th? From the point of view of world history, this century must be characterized as the century of scientific discovery. It was ushered in by the discovery of the electron and today our understanding and control of the atom accounts for a major fraction of the industrial world's GNP. Today, ordinary citizens of modest means command comforts, longevity and the ability to live a fulfilling life undreamed of even by the kings and Rothchilds of the 19th century. Without the scientific discoveries of this century, there

would be no computers, no silicon chips, no genetic engineering, no high temperature or low temperature superconductivity, no fission or fusion, no understanding of why the sun continues to shine, no inkling of the molecular basis of genetic function ... and so on.

Let's review what made the United States the leader of the world and (once) its greatest nation. It started with huge natural wealth in glorious forests, an abundance of coal, oil, high grade metallic ores, rich soil, a varied and benign climate, ample supply of clean water in our wild rivers and great lakes. It profited from beneficial immigration - wave after wave - each one bringing in talent which seemed almost designed to contribute in its time, from the pioneers with their courage and their vision all the way to the current contribution to the melting pot - the Asians who have replaced Jews as the academic superstars in our graduate schools. I include here those who gave us our stable and flexible democracy, who installed compulsory education and land grant colleges - whose vision and statesmanship increased our wealth with the Louisiana and Alaska Purchases - and the wave of European scientists who fled Europe before WWII and changed U.S. science from barely respectable to absolutely pre-eminent. In the Golden Age of 1948 - 1968 U.S. science, technology and ingenuity, combined to dominate in autos, tires, electronics, quality steels, consumer products, machine tools, scientific journals and universities. American English was the world language of communication ....

Then Something Happened

Let me make an incomplete list:

1. Decline of U.S. spirit and innovation
2. Our students turned away from hard subjects in search of something else...

3. We endured the science funding slide of the 70's and began to lose the momentum in science and in education that was fired by our victory in WWII and refired by Sputnik
4. There emerged real competition. Other nations forged ahead. Our cars, tires, machine tools, processed steel, consumer electronics were surpassed as if they were so much junk!
5. This, plus TMI, plus Challenger - caused a failure of our technological self-confidence.
6. Our industries gave up Research Labs in favor of the search for the 3rd quarter profit sheet. Obsession with short range goals dominated our industry and our policy.
7. We became aware of the dark side of technology: the appearance of shortages

   Oil and gas crisis → fossil fuels

   Depletion of high grade iron ores

   Dependence on foreign sources of vanadium, chromium, nickel and other crucial metals

And the even more threatening environmental effects of rampantly deployed technology, another incomplete list:

- Acid rain
- Greenhouse effect
- deforestation
- toxic and nuclear wastes
- garbage disposal
- urban air pollution
- global oil spills
- new and mysterious diseases e.g. Legionnaires and AIDS
- danger to the protective ozone layer

Anyone with a little imagination could make up a new list of crises, <u>not yet encountered</u>, that will <u>no doubt</u> come with the 21st century to torment our grandchildren.

So

How do we find the new sources which will replace the wealth we have depleted? How do we buy insurance against present and as yet unimagined future threats? And how do we cope with the prospects of six to eight billion human beings on the planet in the next few decades AND with the fact that the present problems were brought on in order to supply only 20-30% of the planet's population with the "good life" - leaving the remaining 70-80% in the non-developed world to watch us on television?

THESE PROBLEMS THREATEN OUR OWN STANDARD OF LIVING, EVEN THE SURVIVAL OF THE PLANET WHOSE POPULATIONS SHARE EXPECTATIONS OF AN EVER BETTER LIFE. THEY CALL FOR VISION, COURAGE, AND CLARITY OF THOUGHT.

We must continue to invest in science, in engineering and in the people who become scientists and engineers. It is only in science that the returns on investment can be 10:1 or 100:1 or even 1000:1 and we have anecdotes too numerous to list. History is crystal clear as to the wealth generated by basic discoveries which only continue to increase. Every year new engineers trained in the use of these fundamental discoveries go on to create new devices and new processes which add to the GNP and benefit our society. We can begin to see a change in the methodology of science, what Kenneth Wilson of supercomputer fame has described as the SYSTEMS ERA of Science. Thanks to powerful new theories, computers and other tools, we are learning how the "basic building blocks" fit together in working systems. Wilson also makes a list:

- We understand the structure of DNA, but research is now beginning to understand how it functions to make cells, bacteria, viruses and even cancer.

- We know how the long strings of amino acids join to produce protein molecules, and we are now beginning to grasp how they fold into the molecular factories that operate living cells.
- We know the basic structures of atoms and molecules, but our ability to fit them together to custom-build the new materials needed by industry is still primitive.
- We've managed to sort out many of the chemical species in our atmosphere, but we're only beginning to understand how they interact to produce such phenomena as the much-publicized ozone depletion.
- We've built the first generations of supercomputers, but the human brain shows us that we are still light-years away from the ultimate in computing power. The advanced computers of the future will be vital tools to help with all the above-mentioned challenges.

The eminent economist Edwin Mansfield [Wharton School] has an on-going study of the returns on investment in research and he has reported that in representative fields of academic research, the return on recent (past 15 years) investment is greater than 28%. That is a payback shorter than 3-1/2 years! And it continues, year after year.

The #1 policy lesson is that nothing, absolutely nothing will have a greater impact on the creation of new wealth - than the recruitment into science and technology of the best brains our nation can produce. And these brains must be furnished with an environment of optimism and purpose and with the tools, the science funds, that will buy the new equivalent of the shovels and drills and TNT that were needed to dig up the old wealth. I am of course aware that many other things are necessary in order to improve the wealth of our nation and the comfort of its citizens. We need technology transfer, we need investment capital, product development, marketing. I assume that these issues are addressed by others who spoke before me. However, without the continued evolution of our scientific base, all the short range ideas will bring only short range benefits. The stress on fundamental

research is driven not only by national self-interest but also by the need for global survival.

We do have a lively and reasonably healthy science to build upon. Science, by any objective measure, is bubbling with vitality and has never offered more hope for future advances ... and not just in one or two fields but everywhere. My own field of high energy physics concerned with the world of the infinitely small, merged in recent times with astrophysics and its concerns with the infinitely vast, is on the threshold of major breakthrough. Today, Fermilab has the highest energy, most powerful machine in the world and, with the SSC, we look to a continuation of this leadership. To quote Stanford's Donald Kennedy, neurosciences are enjoying a bounty of experimental discoveries - they have recently begun to understand the signals that guide axons to their proper terminations in the brain so that we are beginning to understand how the brain becomes connected in the right way - also, there is a new ability to analyze the genetic nature of lesions in human neurological disorders from color blindness and muscular dystrophy to depression.

Condensed matter physics and materials research have become hot topics with the breakthrough in superconductivity aided by powerful new instruments e.g. synchrotron radiation, tunneling scanning electron microscopy, short-wavelength lasers and so on. Taken together we are in a position to make science work for the enrichment of culture and for the betterment of the human condition in a way that is unparalleled in our history.

New wealth indeed!

Predictable extensions surely includes a final solution to the energy problem facing the planet; either by the (dubious) potential of cold fusion - or by hot fusion or by some new idea now only a microscopic seed in the brain of a high school kid debating whether he should go into science. It

may appear out of a breakthrough in our understanding of the structure of a proton - made up of quarks. An understanding of the ageing problem may be latent in the mind of another youngster who doesn't even know what science means and whose first grade teacher is even less interested. Genetic engineering offers a tremendously seductive list of promises ranging from designer bacteria trained to improve and protect crops, to increase agricultural yields, to clean up toxic wastes and so on.

Much of this progress has come from the improvement in science funding over the past decade and from the strong base forged in the golden age of 48-68. I don't have an easy answer to the question of recruitment; it involves science education and a vastly greater public understanding and appreciation of science's role in the pace of our times. It is clear that the support of science and whatever educational ideas seem relevant is crucial.

In earlier testimony before Mme. Lloyd's Subcommittee I pointed out that a doubling of our $10B dollar research budget will not destroy the nation - even as President Reagan doubled the defense budget to $300B dollar - and the return on <u>that</u> investment <u>will</u> go very far to providing the new wealth which is the essential ticket to safe passage into the 21st century.

My final point has to do with the quintessential success story of the Japanese. The chart I am enclosing tells only part of the story. We know that Japan has very little in the way of natural wealth. What then is the source of their success? Clearly it is human resources, an intense care for education and of course an ethic that they <u>must</u> succeed. All lab directors share our experience at Fermilab. If you want an intricate, exquisitely complex gadget, you will typically get zero bids from U.S. vendors, one from Germany and five from Japan. The ethic there is, if they can learn anything in the process of making it, they'll bid. This knowledge, they say, will be valuable in the future. What should <u>we</u> learn from this? It is

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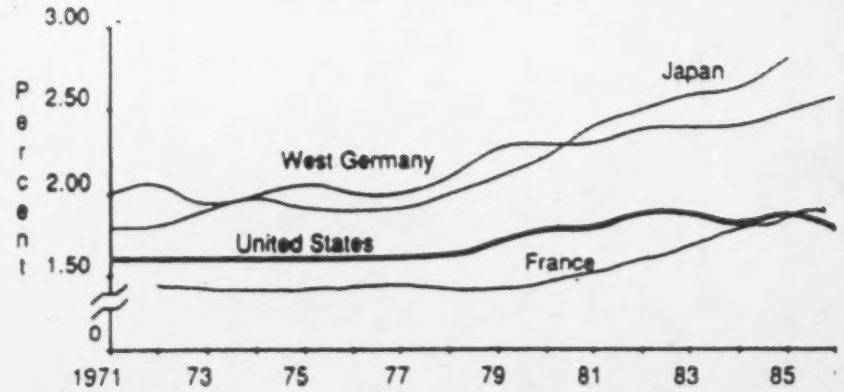
simply that we must have faith in our future and we must learn again how to also think and plan for the long term. After all, the 21st century will be here for a hundred years. Thank you.

U.S. Trails West Germany, Japan and France in Non-Defense R&D Expenditures as a Percentage of GNP



For 15 years, U.S. investment in civilian R&D as a percentage of GNP has lagged far behind that of West Germany and Japan, and the difference is growing. France has now passed the U.S.

Source: NSF

Mr. SCHEUER. Thank you very much, Dr. Lederman.

Can you tell us in a broad, sweeping statement precisely what happened between 1968 and 1988 and what do we have to—in 1989, at present—and what do we have to do to reverse the field? Is it simply a lack of funding? Are there some institutional changes that took place that we have to reverse by making changes in the way that our scientific establishment relates to the rest of society, to Government, to industry, to the universities? What happened, and give us the specifics of it.

Dr. LEDERMAN. Well, I think we are probably familiar with what happened. It was probably triggered by the involvement in Vietnam, and that led to a disillusionment about students in the institutions. Students turning away was important. And then if you look at the trends in Federal funding for science, that declined. That added to almost a chain reaction of discouragement and disillusion, and that long slide of the seventies was a very difficult period.

I do think that in a recovery from that kind of situation—and we lost a lot of momentum. Books that Nobel Laureates had written for high school students in science in the great enthusiasm of the Sputnik period started to get watered down, rewritten, and in a very short time they were back to the old books that had no content and no toughness to them, and all across the board the build-up of momentum in institutional methods of using science funding wisely sort of decayed.

I think if we do now, as we seem to be, recognizing that probably literally survival of civilized society in this planet is going to depend on vastly increased efforts in science and technology and greater understanding of how you deploy these things, that institutions will have to adapt.

It is well known in this country, I think, that we do science in so many different organizations in the administration and in the Congress, and you have all these budget pages where one particular science is matched against rivers and another against something else that have no connection.

Both the executive and the legislative branches are going to have to adapt and streamline their procedures and institutions, and, again, we have to encourage industry to get back into research in a serious way, and we need to have a concentration on long-term issues, because all of these pay-backs you get form science and from education crucial to science take time. We have to have staying power; 20 years is not enough. The average pay-back for a student is 20, 30 years. The anecdotes which go from basic research to commercialization vary from 10 to 30 years. So we need to have a commitment, a long-term commitment, to keeping this steady and not subject to the yearly crises and so on.

Mr. SCHEUER. I thoroughly enjoyed your remarks.

We just did a cost/benefit study of the pay-out to society of the GI Bill of Rights, and it was astronomical. Society said to me and to you, "We do not want you two guys hustling drugs on Times Square. Make something of yourself." Right?

Dr. LEDERMAN. Right.

Mr. SCHEUER. That is what they said, but they said it for all the wrong reasons, because we had given a little time to our military.

They should have done it for the reason that that is what society urgently, desperately needed.

Not only did the GI Bill of Rights—we just did a cost/benefit survey—not only did it produce a return to society of between $7 and $13 for every $1 expended, which makes it the best, all time best investment we ever made, but it produced a cadre of Ledermans—not Scheuers but Ledermans—engineers, scientists, technologists, physicists, the whole scientific establishment after World War II that projected this country into the post-industrial revolution and that established our country as the pre-eminent industrial power in the world. We never could have done it without the cadre of trained manpower that the GI Bill of Rights produced.

Dr. LEDERMAN. I hope we can have another GI bill without World War III.

Mr. SCHEUER. Right. Well, that is what we have got to do. It was an incredibly effective program for our country, but the reason was wrong. We ought to do that now, and we ought to do it because our society urgently needs the development of its human potential, and that kind of a trained layer of manpower demand of a post-industrial society.

Mr. VALENTINE [presiding]. Doctor, let me ask you this question. It has been long accepted that the United States science and technology will remain strong only if Federal funding for research and development rose significantly every year. What do you think about that?

Dr. LEDERMAN. Well, the thrust of my remarks is just so. I do not know—I think the pace—well, in the golden age, the period I referred to, I lived through that, and I always thought it was tough to get money for research; there was resistance to it. Looking back at that, that was a golden age because the resistance was overcome. If you had a good idea, you could get funded to do your research in that period of time. You had to be persistent, you had to believe in it, but you could get funded. that is no longer true now. Too many ideas are not funded, or funded marginally, or funded with such bureaucratic obstructions that it is very difficult to proceed.

So I think that, in my own opinion, there is a two-pronged approach. You have got to cultivate the people. And in connection with your remarks, sir, we do not do enough for the gifted in this country. We are a compassionate society, so you can get $20/$30,000 a year for a handicapped student, but if you have a student who is handicapped by having a brain and therefore he does not fit into his classroom, you can not get $15,000 a year to give him the best possible education, and that is a tragedy in a way and shortsighted.

I think you have to cultivate the human resources. I mean why is Japan successful? It is not their oil, it is not their coal, it is not their hardwood forests, it is not a mother lode of computer chips under Mount Fuji, it is human resources that they cultivate.

We have got to cultivate the human resources, and then we have to yield to their pressure for the scientific tools, with some resistance, but yield to the pressure, and my guess is that that is the kind of funding increase, say, over the next four or five years. We have got to cultivate small science and big science and all good sci-

ence, and I suspect that you will see a slow doubling of the effect of basic research and applied research budgets of this country if you do it that way. But I think that is the way to create the new wealth for profit and survival.

Mr. VALENTINE. Mr. Ritter.

Mr. RITTER. Mr. Chairman, thank you.

It is always a pleasure, Dr. Lederman.

You talk about the golden age where U.S. science was really contributing substantially to economic health and well-being, but even since that golden age we are still, in terms of money spent, the tops. We rank essentially with Japan in terms of per capita expenditure on research and development. But is it not true, the big difference between then and now—in other words, in civilian R&D we spend $68 billion and they spend $39 billion. If you normalize for population, it is not too different.

Dr. LEDERMAN. Do you want to separate military and nonmilitary?

Mr. RITTER. Yes. We spend $68 billion on civilian, nondefense R&D, and they spend $39 billion.

But, in any event, is not the real difference between then and now was, then we did not have any competition? I mean let us face it. The golden age, when America was king of the hill, there was nobody else coming up the hill.

Dr. LEDERMAN. The difference—well, the difference to what?

Mr. RITTER. The difference in why we are holding this hearing, to discuss the creation of new wealth, and you are saying we—in the words of the chairman, you know, we are going to have to substantially increase the amount of Federal R&D support. But could it be that we already have vast numbers of dollars in Federal R&D support and we are simply—we may be not spending them appropriately, since we already have the same essentially per capita expenditure as the competition?

Germany is spending $19 billion on nondefense R&D. Their population is a lot smaller than Japan's as well. But we are just not out of line on dollar expenditures, yet in the global economy both Japan and Germany have, to some extent, dominated us. Could it be that we are dealing with an inappropriate model spending Federal R&D resources?

Dr. LEDERMAN. Well, this is a good and deep question. My own concentration, of course, is on the R part of R&D, and D occupies so much of those numbers you discuss, but I am not really prepared to address that. I do have some figures in front of me indicating that, in fact, in nondefense R&D, if you normalize the GNP rather than per capita, the United States is now behind France, West Germany, and Japan and a factor of 2 below West Germany and Japan and slightly below France. This is as of 1986, and this is the NSF studies, and what you also see is trends. You see West Germany and Japan zooming up; you see the United States fairly flat, although there are recent indicators of some increase. So if you divide by GNP, it does not look nearly that good.

But, again, if you now go to basic research, I think the situation there is even more alarming, and I am looking at more of the long-term effects. Since I am in basic research, I have to look at the long-term effects.

Mr. RITTER. Yes, but, in fact, if I could just interrupt for a second, it is not the basic research success that has led to the success of the Japanese model and the new Asian developing economies. It is not basic research that has led to the success of the German economy. It is technology applied rapidly into products and processes which then, through strategies, a variety of strategies, gain market share.

I just want to be careful that we do not get into a bind here in this committee somehow thinking that if we just spent more money in the way we have been spending money, we are going to get a change in America's global competitiveness. I really do not think it is going to happen.

You mentioned education. The United States spends more per capita—and maybe per capita is important there—of its GNP, a greater percentage of its GNP per capita, on education than any other industrial competitor that we have, except for Sweden, but there are people who are calling attention to the fact that the model for American education is not that relevant to today's world, and I think they may be right.

I think we have got to consider how we are spending the money as opposed to just the money itself. Does that make any sense?

Dr. LEDERMAN. I do not think we disagree. I believe, in fact, it is clear that in education we are not getting what we should be getting for the money we are spending, and that is why I did not stress funding in education.

Mr. RITTER. I mean the associate dean of engineering at the University of Delaware in Newark says that our global competitive disability is due to the fact that the Federal Government spends so much research dollars in engineering colleges that it produced engineering researchers and students who study with engineering researchers and not students who know how to make things, products, processes, process research, process engineering, I mean manufacturing. I mean for 30 years it was a dirty word in a college campus. We do not have any, you know.

Dr. LEDERMAN. I think the basic difference is, you are looking short range and I am looking long range. I think I am looking at, how do we get into the twenty-first century? How do we survive as a nation, of course, to keep our standing of living high, but how do we survive as a nation, as part of a planet, to keep the planet healthy? And both of these things, I think, point to fundamental knowledge, and of course fundamental knowledge without all of the intermediate steps that go from that to product development to commercialization are very important. There is probably lots of things that can be done to help, but my own feeling is that if I look at the things we are profiting from now, they are the basis—they would be nothing without the basic research we had in the golden age.

It is the golden age that produced the knowledge of nuclear magnetism which gave rise to magnetic resonance imaging; it is the golden age that gave rise to the molecular physics that gave rise to the lasers; and it is the atomic and nuclear physics that gave rise to the synchrotron radiation sources which are crucial, and so on, and so on, and so on. And I am looking at that base of fundamental

knowledge from which the technology will be applied. I am worried about my grandchildren and their grandchildren.

Mr. RITTER. I think the simple fact of the matter is, we have been superseded as the world's leading industrial technological power not on the basis of a lack of basic research but on the basis of how science and technology are integrated into economic gain, jobs, standard of living, products, processes, and the like, and unless I think we realize that as the first order effect here we could ensure a second-rate future by simply not being efficient enough about the use of science and technology resources.

Japan is—were you here for Rusty Roy's testimony?

Dr. LEDERMAN. No. I missed that.

Mr. RITTER. Well, Rustum Roy called us the science producer and called Japan the science eater, and the way science is distributed globally today instantaneously, the basic work is not proprietary, it is available for the globe, and, you know, England proved how many Nobel Prizes you could win and still go downhill as a global industrial power.

Dr. LEDERMAN. I had a conversation with the president of the National Academy of Sciences of Japan not long ago in which he admitted that the Japanese have been riding on U.S. basic research in that golden age, and he said, "Now," he says, "you're too slow; we can not wait for you to keep doing this; we are going to do it ourselves." And, indeed, if you look at what is happening in Japan, the basic research stuff is going out.

Mr. RITTER. Thank you, Mr. Chairman. I yield back.

Mr. VALENTINE. Mr. Mineta.

Mr. MINETA. No question, Mr. Chairman, other than to thank Dr. Lederman for his leadership. I am just hopeful that as we look to the future, I just hope that we will be able to continue a leadership position, and we really do look to you and all the other national labs to do that for us. And I think there is a basic problem, and that is that we have to distinguish between leadership in R&D versus looking at the trade imbalance, and I think there is a difference in a sense that, as you have indicated, we are the maker—we make the science and Japan eats the science, and I think that is where they utilize and put their R&D monies into two areas: one, commercialization of product; and, the other, R&D and manufacturing; and that part is where we have the disconnect, and so we do the basic science, but we do not get into the marketplace with it, and so hopefully we will still be able to continue the resources to you and your colleagues so that we can still make that continued breakthrough in terms of basic science, and hopefully, hopefully, get a connect so that we can get to the marketplace, and get that trade imbalance down, and keep our educational and employment base up.

Thank you very much, Dr. Lederman.

Mr. VALENTINE. Thank you, Doctor. Perhaps some day soon we shall meet with a more optimistic message from you.

Mr. RITTER. Congratulations, too, on the Nobel Prize.

Mr. LEDERMAN. Thank you very much.

Mr. VALENTINE. Yes, certainly.

With that, the committee stands adjourned until 10 o'clock tomorrow morning at this same place.

[Whereupon, at 1:30 p.m., the subcommittee was adjourned.]

CREATING THE NEW WEALTH: NATIONAL RESEARCH AND DEVELOPMENT FUNDING IN THE 1990s

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WEDNESDAY, APRIL 12, 1989

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D. C.

The committee met at 10:50 a.m. in Room 2318, House Rayburn Office Building; Honorable Robert A. Roe, chairman, presiding.

Present: Representatives: Roe, Scheuer, Volkmer, Nagle, Skaggs, Johnston, Tanner, Boehlert, Ritter, Smith [TX), Morella, Shays, Rohrabacher, and Campbell.

Also present: Dr. John Holmfeld, Science Policy Staff, Robert C. Ketcham, General Counsel, and Christopher Wydler, Republican Legislative Director.

The CHAIRMAN. The committee will come to order. The Chair apologizes for being late, but we had a thing I had to do on the floor.

We are going to continue our hearings today, broad- based, "Creating the New Wealth: National Research and Development Funding for the 1990s." We had an excellent hearing yesterday, with a great deal of very valid information that the committee needed and can work with.

The first witness today is Dr. Ralph E. Gomory, Senior Vice President, Science and Technology, IBM Corporation, Armonk, New York.

The Chair wants to welcome you, Doctor, to our hearings. You go ahead and proceed. Your statement will appear in full in the record, but you are welcome to either do your whole statement or summarize, whatever is best for you.

[The biographical sketch of Dr. Gomory follows:]

RALPH E. GOMORY

IBM Senior Vice President for Science and Technology

International Business Machines Corporation

Ralph E. Gomory, IBM senior vice president for science and technology, heads an organization which consolidates the company's Research Division (with laboratories in Yorktown Heights, New York, San Jose, California, Zurich, Switzerland, and Tokyo, Japan), and IBM's science and technology assessment and university relations functions. He is also a member of the Corporate Management Board.

Dr. Gomory graduated from Williams College, studied at Cambridge University and received his Ph.D. in mathematics from Princeton University in 1954. He served in the U.S. Navy and was Higgins Lecturer in Mathematics at Princeton before joining IBM in 1959 as a research mathematician at Yorktown Heights. In 1964 he was made an IBM Fellow, a rank conferred on a small number of scientists and engineers in IBM. In 1970 he was named director of research, and in 1973 elected a vice president of IBM. He was named a member of the Corporate Management Board in 1983, elected a senior vice president of IBM in January 1985, and named to his current position in September 1986.

Dr. Gomory has been elected to the National Academy of Sciences, the National Academy of Engineering, the American Philosophical Society and the American Academy of Arts and Sciences. He is a Fellow of the Econometric Society. He was elected to the Council of the National Academy of Sciences from

1977-1978 and 1980-1983, and served on the Governing Board of the National Research Council from 1980-1983. In 1986 he was elected to the Council of the National Academy of Engineering and to the Council of the American Philosophical Society. He served on the White House Science Council from 1986 to 1989.

In 1987 Dr. Gomory became a member of the Council on Foreign Relations and chairman of Harvard University's Visiting Committee for the Division of Applied Sciences. In 1988 he became a member of the University Council on the Graduate School of Yale University, the Carnegie Corporation of New York's Commission on Science, Technology and Government, the Advisory Council to Princeton University's School of Engineering and Applied Science, and Massachusetts Institute of Technology's Visiting Committee for Electrical Engineering and Computer Science.

In 1987 Dr. Gomory was named chairman of the Advisory Committee to the President on High Temperature Superconductivity. In 1989 he became a member of the newly established National Commission on Superconductvity.

Dr. Gomory is a trustee of Princeton University and the Alfred P. Sloan Foundation, and has been a trustee of Hampshire College. He has been an Andrew White Professor-at-Large at Cornell University. He is a director of the Bank of New York, the Industrial Research Institute, and Nova Pharmaceutical Corporation.

In July 1988, Dr. Gomory received the National Medal of Science from President Reagan. Previously, Dr. Gomory was

awarded the Lanchester Prize of the Operations Research Society in 1964, the John von Neumann Theory Prize given jointly by the Operations Research Society and the Institute of Management Science in 1984, the Harry Goode Memorial Award given by the American Federation of Information Processing Societies in 1984, and the I.R.I Medal given by the Industrial Research Institute in 1985. In May 1988, he received the Institute of Electrical and Electronics Engineers (IEEE) Engineering Leadership Recognition Award.

Dr. Gomory holds honorary Doctor of Science degrees from Williams College, Polytechnic University, and Syracuse University, and an honorary Doctor of Humane Letters degree from Pace University.

Dr. Gomory is the author of over fifty technical papers.

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March 1989

STATEMENT OF DR. RALPH E. GOMORY, SENIOR VICE PRESIDENT, SCIENCE AND TECHNOLOGY, IBM CORPORATION, ARMONK, NEW YORK.

Dr. GOMORY. I want to thank you, Mr. Chairman, for giving me this opportunity to talk about this subject on which I have spent such a large portion of my life. I do not think there can be the slightest doubt that new knowledge and understanding has enormous potential for creating wealth and material well-being. Now, that has been illustrated over and over again. The fundamental understanding of solid state physics is what made possible the transistor, with the subsequent transformations wrought by the computer revolution. And the fundamental understanding of molecular biology has made it possible to see the beginning of another revolution, which is the biotechnology one.

So I think that the issue for our country is not whether science creates wealth, but whether the United States can get a reasonable slice of it. And it is that relationship between scientific leadership and its translation or its relation, because it is more than the translation, that I want to talk about today.

We sometimes wonder how the greatest scientific power in the world—and this country is that—can have so many industrial competitiveness difficulties. However, this separation of scientific leadership and industrial power has historic precedence, and we have been on the other side of it because certainly in the 1920s and 1930s, which I can actually remember, the U.S. was the leading industrial power of the world by any measure, whether per capita production measures or total, at a time when it was not a significant scientific power.

So, with that and the Japanese example before us, I think we have to look realistically and not impressionistically at what is the connection between fundamental understanding and scientific leadership and having competitive product. It is my purpose in this statement here to give a very quick view of what that relationship or, more accurately, those relationships—because there can be more than one and they are very different—what they are.

First of all, I would like to make a distinction between new technologies and other things. There are often new and dramatic developments, of which the transistor is a perfect example. And in these developments, like the transistor, a new idea comes along, and a product is formed around that idea. In this process, which is sort of the birth process of a new industry, the new idea is the important thing and the people who understand it are the important people. So in the early stages of transistor, you see scientists not only explaining how it works, but making it work in practice, and playing a major role in bringing out the early product.

Very often when we think of industrial competitiveness, we think of this model, the new idea and the new technology being born. However, it is important to realize, and it is very relevant to our competitive position, that there is another form of innovation which is far more common and has the property in the long run that tends to determine the competitiveness of an industry.

We call that first process in which an idea becomes a product, a new idea becomes a new product, we call that the ladder process

which visualizes it, so to speak, its descent from the scientific realm into product. There is another process which I will call the cyclic development process. It is a lot less dramatic, but it is a lot more common, and it's pervasive in most industries. It is this process in which an existing product, not a new one, improves every year, gets new features, becomes easier to manufacture or cheaper. It is this kind of process, for example, that has given us every year not the original chip, but more bits on every memory chip year after year, so that they have evolved in the past 25 years from having one bit of information on a chip to more than one million. And this process of incremental improvement will go on, and we will have four million and then we will have 16.

The reason this cyclic process—and I will explain in a moment why I call it cyclic—is so important is because if you look around in any given year, most competition is not between some brilliant new idea and the old, but between variants of the same product. It is my automobile versus your automobile, not my automobile versus your jet-propelled helicopter. So very often, the decisive thing is who can increment this thing better.

Incidentally, it is the nature of our current industrial weakness that it shows itself in this process, not in originating, because if we ask ourselves who originated semiconductors, it was the United States. Who had the early lead in translating that scientific knowledge into product? It was the United States. But who lost a very large share of the memory market, not to some new form of memory, but just to a slightly more refined and more rapidly manufactured form of memory? It was the United States. So that our weakness has not been in the first process, the reduction to practice of a new technology; our weakness has been in the long race that follows, which is a race of small improvements to an existing product.

We were certainly early in the automobile business, and we were certainly early in the consumer electronics business. And in all of those, we were the original innovators and the original leaders. But I have now named the three industries, the three high-tech industries which, with textiles, make up the balance of trade deficit. And we started them all, and we lost them all later. So we had better understand the connection of this incremental improvement process because that's where the current weakness resides.

I am going to describe this a little bit. The first point I want to talk to is the cyclic nature of the process. What does that mean? It just means this: that while the current product is being manufactured, someone is working on the next product. So one of these things gets designed, it gets to be put in the manufacturing line; the team that designed it turns around—I am simplifying a little bit, but this is the essential notion—starts to design the next version. That is the way it goes.

This is a little different from the idea-centered thing. That is, the next product is kind of an improved version of what is there. And if you can improve it, you have got to know what is there. So this process which is so important is not centered around a new idea. It is centered around the existing product. You tend to improve it a little bit. You put a better head in a disk. You put a better head in a printer, the part that prints. But it has to fit the existing printer.

It is a very important point, that it is centered around what is already there. It is also centered around the tools that are already there. It is also centered around the knowledge of the practitioners. What they understand matters, because if they are used to working with metal A and you propose metal B, they do not know what to do with it in time.

I just said "in time." What does that mean? With this thing, which one thing is designed and it goes into manufacturing, you turn around and design the follow-on and put that into manufacturing, speed is very important. Just think. Supposing you have two companies and one can turn it around in the sense of going from the beginning of a design into manufacturing in two years and the other one takes 3-1/2, both companies let us say have, so to speak, the same set of ideas, know the same technology, they would in practice design the same thing. Say it is a printer. But one of them gets it out in two and the other gets it out in 3-1/2. The one that gets it out in two will be viewed as a technological leader because basically the technology, when it hits the marketplace, is two years old; and when the other guy's technology hits the marketplace, it's 3-1/2 years old. One is a technological leader not because he invented anything, but because his translation into practice took two years and the other one took 3-1/2.

And by the way, if he turns around, he can do it twice in four years, three times in six years, and the other guy won't even have his second edition out. So one will run away from the other. He will run away on the basis of speed of the manufacturing development cycle, not on the basis of generating anything new at all.

This is a very, very important element when you understand this cycle, how fast you can turn it around. What are the things that affect that turnaround? One of the things very definitely is a close tie between the manufacturing people and development people.

You could design a printer and it could be the world's greatest printer, and it prints beautiful black characters, and it prints all shapes of characters, but supposing it's really hard to manufacture. It will take a long time for the manufacturing people to find out how to make it in large numbers—the development people only make it in very tiny numbers for test—and it will take a long time before it comes out. And now you have a long cycle and you will be disadvantaged by someone who has teams of development and manufacturing people working closely together so they design something that's manufacturable.

So there are two points there. A lot hinges here on close ties between manufacturing and development, and the second thing sort of rolled up in that—you want to design the thing to be manufacturable. We have had very spectacular examples in IBM, compared sort of before and after, in which we really focus on making something easy to manufacture and it comes out more reliable and it comes out cheaper and it comes out quicker.

So, oddly enough, design for manufacturability, just like speed, will appear as technical leadership when it come to product.

The third point I would like to make very briefly is that it is very important that the people who are the actual participants in this process, the engineers let us say, and the manufacturing people, have to be educated, they have to be aware of what is going

on in the outside world. That may sound obvious. It is not in practice because they tend—people say, "Get your job done. Don't travel. Don't go and visit the universities. Don't go to this meeting, because you have got to design that thing or you have got to get these pieces manufacturable."

But, in fact, given that this is a product-centered process, not a new idea-centered process, these are the only guys who know what new ideas can in fact be incorporated into the new product, into the next round of the product. They are the only ones who know the exact dimensions of the head, they are the only ones who know what tools are available. And if they have their heads down and they are impervious to anything they are aware of on the outside, nothing is going to happen.

It is very hard to push new ideas from the outside into the manufacturing development cycle because it would be an accident if it fitted. What you really need is the engineers who understand all the details going out and pulling in those things that fit. It is a situation in which pull is necessary and push will hardly ever work.

This relates, of course, in turn to who can help improve this process. The answer is to the first approximation, the members of it, the people in it. It is very hard to effect it from the outside.

So let me wind up by just summarizing what I am saying. There really are two kinds of innovation in the world, the ladder kind and the cyclic development kind. The ladder kind we associate, correctly, with basic research, new scientific ideas, and their first time reduction to practice. And in this scientists play a role. It is a lot easier, by the way, to see what the government role can be, because all of this happens outside of the existing product stream. And universities and government labs and so forth have in the past been contributors.

But once an industry is started around some new idea like the transistor, and once it develops, it is in a totally different phase. It is in cyclic development process of incremental improvement, and that game is dominated by the engineers and the manufacturing people, and they are relatively impervious to new ideas from the outside unless they themselves are the ones who go out and pull them in.

Now, the United States has been extremely effective in the ladder process, the introduction of new ideas. Its main problems to date—and I say "to date" because it could be changing—have been in the long race that ensues in the cyclic development process, in turning that cycle fast and making incremental improvements. That is why we have started industries and then seen them get away from us.

In the long run, to be competitive we have to learn to do both, to be not only competitive in the ladder process, but in the cyclic process. I think we need enormous improvement in the cyclic phase. In doing that, we should not let go of the ladder phase, because the Japanese are making very intelligent and very coherent efforts in new technologies as well as in the excellent execution of incremental improvement.

So that is the picture that I wanted to lay before this committee and I thank you for your attention.

[The prepared statement of Dr. Ralph Gomory follows.]

TESTIMONY

R&D and Industrial Competitiveness

April 12, 1989

Ralph E. Gomory

Committee on Science, Space and Technology

Thank you, Mr. Chairman, for giving me this opportunity to appear before your committee. I am Ralph Gomory, IBM's Senior Vice President for Science and Technology. I am pleased to discuss the important issues surrounding R&D in the United States, and how R&D relates to our industrial competitiveness.

A number of unpleasant facts are forcing us to rethink this relationship, including the success of foreign products in our market, our relative inability to compete overseas, the decline of some major industries, and our nagging trade deficit. Giving our convictions about the importance of science for competitiveness, we sometimes wonder how this can happen to the greatest scientific power in the world -- a country that has more Nobel Laureates and makes more breakthroughs, large and small, than any other.

However, this separation between scientific and industrial power has historic precedents. The U.S. was the leading industrial power long before becoming the leading scientific power. For much of the 20th century, we demonstrated what Japan is reminding us of now: product leadership can be built

on design and production know-how coupled with imported science. Discussions about what needs to be done to make U.S. products more competitive often move to discussions of who invests more of their GNP in basic research or who has the most scientists and engineers per capita. But, the connection between these statistics and the fact that we watch Japanese TVs is not at all clear.

I'd like to look realistically and closely at the real connection between science and product. First, there is not just one fundamental connection, but two. The first is the reduction to practice of some new scientific concept. Two examples you'll be familiar with are the transistor and the atomic bomb.

These are often dramatic developments wherein the new concept dominates, and products adopt themselves to that new science. I call this step by step reduction, the "ladder" process. This is what most people think of when innovation is mentioned.

There is, however, a less dramatic connection. I call this the "cyclic development" process -- the process of repeated incremental improvement. It may be less dramatic, but it is profound in its implications. In this process, an existing product is improved by the addition of new features, year

after year. This is primarily the world of engineers, not scientists.

It is this process, for example, that has given us every year more bits per chip and thus cheaper computer memories. In the past 25 years of incremental improvement, we have come from one memory bit on a chip to more than 1 million, and the incremental improvement process continues with 4, 16, and 64 million bits on the way.

The reason this cyclic process is so important is because competition is usually between variants of the same product. It is car vs. car, not car vs. helicopter. Here is the important point: incremental improvement is a process at which our international competitors excel. Where we have lost ground, it has generally been to better existing products than to radical new technologies. TVs, computer memories, cars -- they all fit into this paradigm.

This is the nature of our current weakness, and it will not be cured by improving our science at which we are already the world's best. With that in mind, I'd like to discuss the cyclic development process more closely for clues to improving our competitiveness.

The first point to recognize is the cyclic nature of the incremental product improvement process. While the current

version of a product is in manufacturing, a development team is already working on the next generation. So, as I noted earlier, in the microelectronic industry, for example, manufacturing could be making 1 million bit memory chips, while development is working on the process, refinements and design for 4 million bit chips.

The second point is that this incremental product improvement is, by definition, a process centered around an existing product, not a new idea as in the ladder process. Moreover, this product cycle tends to be relatively impervious to ideas from outside sources. This is because the people who decide what should happen next are those already involved in the product cycle, the engineers.

We can draw some important competitive lessons from this cyclic development example. First, speed is crucial. To a very great extent, how quickly a company can bring its next generation of product to the market will determine its ultimate success in that market. Suppose two companies have access to the same set of ideas, but one can go from designing the next generation to manufacturing in two years, while the other takes three. The company with the two-year cycle will appear the technological leader even though both are working from the same storehouse of technology. It takes only a few turns of that cycle for the company with the shorter cycle to build a commanding lead.

My second competitive lesson is the importance of close ties between development and manufacturing. Close ties encourage better design for manufacturability. Early discovery of technical problems can translate into speed of introduction and improved quality. This requirement is well practiced in Japan, where development and manufacturing engineers work side by side with equal respect. As a result, Japanese product designers focus on simplicity and cost containment. In the United States, however, product designers focus more on features and performance than cost or simplicity. That's too bad because the results can have a range of important effects from something as simple as one screw size for an entire computer mainframe to something complex like designing a new product with two-thirds few parts than its predecessor. This is an area where IBM has had considerable success.

My third lesson drawn from the paradigm is the importance in keeping engineers technically current. I mentioned earlier how difficult it is to insert ideas into the product cycle from outside. Consequently, product engineers themselves must be well informed on the relevant science and technology. They must be encouraged to attend conferences, read the technical literature, learn what is going on in universities, and become active participants in the overall engineering community. If they are <u>not</u> up to date about what is happening technically outside their company, a high level of technology in the

infrastructure will go to waste, or more likely, seized upon by a competitor.

The eagerness of Japanese engineers to learn what is going on in the rest of the world is legendary, and its importance is clear. Japanese engineers are more willing than their U.S. counterparts to learn about what others have done, and they make a strong effort to be educated on the relevant technologies and the competition's products.

Finally, a company that wants to be competitive must invest heavily in the continued education of its people. Continuing technical "up-to-dateness" requires efforts from both employers and employees.

I'd like now to discuss the role of research. As with developers, researchers must have close ties to the product process if they are to assist incremental product improvement. Such ties are difficult to achieve, especially if relevant research is on the campus of a university separated from the product cycle activity. The greater the distance, the greater the difficulty in understanding industry's requirements. And, because university specialists can't possibly know what's going on throughout industry, it is incumbent upon scientists in industry to become familiar with academic advances in science and technology. They must reach out to the universities and "pull" back the relevant information.

I do not learn to limit in any way the role of academic research, its record is terrific. And it has, perhaps, the major role in "ladder" type innovation. In the long run, this is very important because today's ladders are tomorrow's industries.

There is much talk of strengthening our infrastructure, our science base and our education system. It is true, a strong science base provides the storehouse of new ideas, as well as trained scientists. This has been a great strength of the United States. Likewise, a good education system provides engineers and manufacturing workers with skills required to run our factories. And with respect to our infrastructure, my company and I have made specific proposals designed to develop and enhance the U.S. infrastructure in areas such as superconductivity, semiconductor technology, and X-ray lithography. But I must say, Mr. Chairman, as good as these proposals are, and as necessary as they may be, they cannot overcome weakness in the product and manufacturing cycle. That is something U.S. companies must do for themselves.

In conclusion, Mr. Chairman, the U.S. has been very successful at "ladder" type innovation. What we must learn to succeed at is incremental product improvement -- the rapid, cyclic process I talked about earlier.

In doing so, we need to distinguish between the short term and the long term. Basic research, education and infrastructure development are important long-term investments. Many, in realizing this, become pessimistic about out ability to compete, but my message is different: important changes are possible in the short term. We can have fewer parts in our design. We can design for manufacturability. We can shorten the product cycle. We can learn to do these things. We can learn to be more competitive.

In short, neither the ladder nor the cyclical innovation process are substitutes for the other. We need both, and we can excel at both.

Thank you very much.

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Ralph E. Gomory

Turning Ideas into Products

It is the speed of the development and manufacturing cycle that appears as technical innovation or leadership.

Ralph E. Gomory (NAE) is senior vice president for science and technology of the International Business Machines Corporation. This paper is based on Dr. Gomory's 1987 *Research & Development* magazine Scientist-of-the-Year lecture, presented 17 September 1987.

Events of the past 40 years have demonstrated in unforgettable ways that science, in addition to being a stimulating intellectual pursuit, has enormous practical power. This power has been made evident to everyone.

It was evident first in the stunningly sudden appearance of the atomic bomb—the practical result of the gradual buildup of knowledge about the atomic structure and the nucleus over the previous 40 years.

A second example of the practical power of science was the appearance and rapid evolution of the transistor — again, the result of a steady buildup of scientific knowledge (this time, about quantum mechanics and solid-state physics) since the 1920s. Today, this development, in the form of silicon chips, is rapidly transforming the world around us.

A more recent example is the spectacular scientific success of molecular biology and its practical ramification — biotechnology — which seems well on the way to affecting living beings themselves in a profound and transforming fashion.

Scientific versus Product Dominance

Since World War II, the United States has been the dominant scientific power of the world. But, to the surprise of many, automobiles, steel, and semiconductor memories have shown us that dominant science does not automatically mean dominant *industry*—even in the most high-technology areas. But we should realize that it never did. Long before, as well as after, World War II — before the world was devastated and the other industrial nations weakened — the United States was the dominant industrial power of the world. In the 1920s, for example, the United States produced more than twice as much iron, steel, and electricity as France, Germany, and Britain combined (and also more than twice as much per capita). It was on this kind of massive and efficient industrial base that were built the overwhelming air and sea armadas of World War II. All of this was done on a negligible U.S. science base. The capital of science in the early 1900s was Europe. One could say with some truth that we were the "Japan" of that period.

To understand why dominance in science does not necessarily mean dominance in products — and how the United States today can continue to excel in generating new scientific ideas, but not so much in generating competitive products — we need to think more concretely about the *connection* between science and products. We

need to realize that the dominance of science and scientists in creating the atomic bomb, the transistor, and biotechnology provides an example or paradigm for the introduction of radically new technology, but not a paradigm for the more ordinary process of product improvement.

Two Different Development Processes

The radical process I have been talking about so far (that produces, for example, a transistor), I call the "ladder" process. It is the step-by-step reduction to practice of a new idea. That new idea being dominant, the product forms itself around the new idea or new technology. And those who understand this idea or technology (often scientists) play the dominant role. However, there is another (indeed, much more common) process of innovation, which I will call, in contrast to the ladder, the "cyclic development" process, or the process of repeated incremental improvement. In this type of improvement process, an existing (not new) product gets better and develops new features year after year. Though that may sound dull, the cumulative effect of these incremental changes can be profound.

It is this process of incremental improvement that — following the initial great ladder-style invention of the transistor — has given us every year larger and better computer memories. In the past 20 years of incremental improvement, we have come from one bit on a chip to 1 million bits. Incremental improvement is also the process that each year gives us higher-resolution display screens, quieter and better quality printers, and so on. This process of gradual improvement is enormously important. Most products sold today were here in slightly inferior form last year, and most competition is between variants of the same product. Competition is usually my auto against your auto — not my auto against your helicopter. In areas where the United States has not been competitive, it has lost — insofar as technical factors are concerned — usually not to radical new technology but to better refinements, better manufacturing technology, or better quality in an existing product.

Characteristics of Cyclic Development

One important point to realize is that the world of incremental product development is, by definition, a world built around the existing product — not, as in the ladder process, around a new idea. The people who know that existing product best, and who decide what happens next, are the ones already involved with it. And what they can do to improve the product is strongly affected by what it already is.

A second point to be aware of is the cyclic nature of the process. In the world of computers, printers, and displays, while the current version of a product is in manufacturing, a development team is working on the next product generation. For example, manufacturing could be making 256-kilobit (K) memory chips, while development is working on the process, other refinements, and the design for a 1-megabit chip. When they are ready, the megabit chip is introduced into manufacturing, which gradually builds up production and phases out the 256K chip. Then the development process starts over again on a 4-megabit chip. A similar cycle of improved product and new production applies to most products in my industry, and to the products of many other industries as well.

The product engineers themselves must be well informed on the relevant science and technology. . . .

Speed Is Crucial

One consequence of this cyclic process is that the speed of the development and manufacturing cycle is crucial. If one company has a three-year cycle and one has a two-year cycle, the company with the two-year cycle will have its process and design into production and in the marketplace one year before the other. The company with the shorter cycle will appear to have newer products with newer technologies. But, in fact, both companies will be working from the same storehouse of technology. It is the speed of the development and manufacturing cycle that appears as technical innovation or leadership. And it takes only a few turns of that cycle to build a commanding product lead.

A key factor in the speed of the cycle, as well as in its quality and cost, is the relationship between development and manufacturing. Design for manufacturability results

in a rapid start-up of production. Likewise, close ties between manufacturing and development translate into early knowledge of technical problems, into speed of introduction, and into quality. And the lack of these ties does the opposite. Another common feature of this development and manufacturing cycle is its relative imperviousness to ideas coming from *outside itself.*

Getting Ideas into the Cycle

If you want to get new ideas into the cycle from the outside, there is a right moment. You need to propose them at the *beginning* of the cycle; halfway through is too late. If you propose a better print-head one year into a two-year printer development and manufacturing cycle, the proposal is useless. Furthermore, even when the new concept *is* available at the start of the cycle, it will need to be pretty well fleshed out and tested so that the development team can expect to finish their work on the idea in time. Another complication is the fact that the product is often too complicated, or uses processes that are too complex, to be understood completely. Examples are electroplating baths of unknown composition or effects, reactions of ions in a plasma with surfaces, or even the vibrations and other factors affecting the flight of a read-write head over a magnetic disk.

Often in development and manufacturing, you do not know exactly how something works, but it worked last time. In this situation, small evolutionary changes are clearly more acceptable than large radical changes. All these things are manifestations of the fact that the existing product is there and is being refined by new ideas. The product, its complexities, what the development and manufacturing teams know or do not know . . . these are the factors that often dominate. And these factors often are understood only by the development teams themselves. This is nothing like the transistor ladder paradigm, where a whole new device is built around a new idea. All of these facts weigh heavily against ideas from the outside, and even more against ideas at a university level of development.

Keeping Well Informed

If new ideas are difficult to get into the cycle from the outside, then those people who are part of the cycle and who understand the present state of affairs in detail must themselves be the bearers of new ideas. This means that the product engineers themselves must be well informed on the relevant science and technology, for they are often the only route in for new ideas. And if they are not up to date about what is happening technically in other companies or in universities, a high level of technology in the infrastructure will go to waste—or, more likely, will be seized on by a competitor. The travel-to-meetings budget, reading the technical literature, being a part of the overall engineering community — all of this is not a frill, nor is it an indulgence to the professional ambitions of the engineer. It is a *necessity* if we are to compete with those who do make these efforts, and thus are better able to incorporate change into their own complex product worlds.

Factors in Effective Competition

Our most effective foreign competition to date has been characterized by

- Tight ties between manufacturing and development;
- An emphasis on quality;
- The rapid introduction of incremental improvements often known to all in the development cycle of a preexisting product; and
- A tremendous effort, by those actually in the product cycle, to be educated on the relevant technologies, on the competition's products, and on what is going on in the world.

These are the things at which the United States, too, must excel. Much of what needs to be done in U.S. industry emerges from a better understanding of the cyclic development process: closer ties to manufacturing, design for manufacturability, a rapid design cycle, and ensuring the technical up-to-dateness of the engineers themselves. Another thing that emerges from this picture is the self-contained nature of the product development world, and the factors that make this world relatively hard to affect from outside itself.

What about Outside Factors?

Nevertheless, let us look briefly at several elements outside the development and manufacturing cycle. The first is the important area of the company's own in-house research organization.

An organization for research (as opposed to development) in industry must be closely tied to the product improvement cycle if it is to succeed. Only through close ties to development and manufacturing can it understand the progress of the cycle, present new steps at the appropriate time, and have them fleshed out enough to be acceptable. Familiarity at a personal level also helps to

build this acceptability. All of this is much harder to do from a university base and even harder from government laboratories as they are now constituted.

Second, cooperative intercompany research (not development and manufacturing) can sometimes help — especially if it is performed by temporary groups made up of people who afterward return to their home companies with new knowledge, and there reenter the cycle. Further considerations include reform of the educational system, strengthening the national science base, and so on. These things are all good and help build a strong foundation — a strong infrastructure. But they are unlikely to affect the development and manufacturing cycle itself in the short run. Their effect will be less direct and more long term. Indeed, it may be that governmental policies in this area need to be formulated with the properties of the development and manufacturing cycle in mind.

The United States has been very successful at the science and scientist-dominated "ladder" type of innovation, where a wholly new idea moves from research into a wholly new product. But there is no escaping the fact that we must learn to succeed also in the rapid, cyclical, engineer-dominated process of incremental product improvement. Neither process is a substitute for the other. We need both.

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RALPH E. GOMORY
HAROLD T. SHAPIRO

A Dialogue on Competitiveness

Two thoughtful observers discuss what science, technology, and education can and cannot do to reestablish U.S. industrial leadership.

"Competitiveness," or the growing lack of it, has been a major issue in the United States for several years. But some are becoming concerned that the discourse remains too abstract—at the "bumper sticker" level—and not sufficiently attentive to where the real problems are and what to actually do about them. Unless we get down to the nuts and bolts, they say, there will be more talk but little action, and solutions that do get implemented will be misguided and ineffectual.

Coming from different backgrounds and positions, ***Ralph E. Gomory*** *(senior vice president for science and technology at IBM) and* ***Harold T. Shapiro*** *(president of Princeton University) have each begun lobbying for greater directness, simplicity, and realism about the things that may, or may not, help the United States to compete: Where we really need to be "the best," and where such distinctions do not necessarily translate into leadership; where the limits of universities lie, and where industry must pick up the reins; where greater science literacy is needed, and where the good old three R's are quite sufficient; where technical savvy is good, but working with and respecting many types of people is better.*

Intrigued by the usefulness of their approach and its likely appeal to our readers, Issues in Science and Technology*—with the aid of the Government-Industry-University Research Roundtable and the Committee on Science, Engineering, and Public Policy—arranged a meeting between Drs. Gomory and Shapiro last May in New York City. What follows is an edited transcript of their provocative discussion.*

GOMORY: A lot has been said about the connections between basic research in universities and economic competitiveness, but that relationship is often extremely remote. The competitiveness "process" takes place in industry, at the level of the individual company. What happens in the university laboratory, no matter how promising from a scientific point of view or how potentially important to industry, is often irrelevant because companies cannot or will not use it.

SHAPIRO: The remoteness is even worse than that, I think. Not only is there a chasm between developments in a university lab and industrial competitiveness, even when the new ideas *originate* in industry

there is likewise a very big gap between that knowledge and its effective use. Being first in science doesn't mean that someone else can't capture the associated economic and social dividends through better implementation.

GOMORY: That's right. And I think it fits into kind of a life-cycle model about new ideas: You can be the first to introduce a new product based on a new idea—say, the transistor—and universities can play a major role in the early stages. But once it is a product and is out there, the ground rules change—it becomes subject to the process of successive refinements. And that is the race we lose—a race largely run by industries. You can say in an oversimplified way that the universities are doing their job, which is the generation of new ideas, but that industry is doing less well at refining those ideas.

SHAPIRO: I have an interesting example of exactly what you're talking about, Ralph, and that's in the American automobile industry. It takes five years to go from concept to what they call "Job One"—the first car rolling off the line. Meanwhile, our competitors are roughly in a three-year cycle, which puts us two years farther from the market in consumer tastes.

GOMORY: There's also the technical dimension: If one company has a five-year development and manufacturing cycle and the other has a three-year cycle, the latter will look like a technical leader. When its car comes out, the product will have a more recent design, more modern materials, and more highly evolved technology. None of this has anything to do with whether the company with the shorter product cycle invented these features; it just means that it's using ideas at a level of knowledge that is two years more advanced.

SHAPIRO: Most of the examples people use in this kind of discussion come from the manufacturing sector. But I'm worried about the productivity of our service sector as well. I studied in one case an accounts payable function for a very large U.S. corporation and it turned out that a staggering flow of paper was involved just to deliver a part to a machine. I studied the same function with a Japanese firm and it required only one-eighth the support. At the heart of this difference was a qualitatively different relationship between purchaser and supplier, as well as between workers and management at the production facility itself.

GOMORY: I share that worry, Harold. And in the comparison you cite, it seems to me that the difference is directly related to how groups work together. Where there is closeness and trust, between manufacturer and suppliers or between different sections of the same firm—built-up levels of confidence, in other words—those huge paper flows are unnecessary.

But closeness and trust are unlikely when there is separation between principal players, and that is the case within most U.S. companies—development and manufacturing people, for instance, live in different worlds. In U.S. industry, the high prestige is in development. That's where the engineers are, that's where design is, that's where the education is. The manufacturing task is considered to be relatively dull, repetitive, and for uneducated people. Therefore production considerations have not been an early part of the design, say, of a new car or computer or printer. Until very recently, the product was not designed to be manufactured. It was designed to work, to make good print, or to run fast, but it was not designed to be manufactured. When the prototype was ready, you simply handed it to a different group of people—the manufacturing people—and you said, "okay, I made one, you make 10,000."

In Japan, curiously enough, it is the other way around: Manufacturing calls the shots. Manufacturing people are highly trained, but people also move back and forth a good deal between various functions. The distinction we tend to make between the engineers in development and those who replicate their designs doesn't exist in Japan.

Similarly, there are harmonious relationships between manufacturers and suppliers. Often the company *owns* a lot of its suppliers. But even with those they do not own, long-term and trusting relationships are the rule. I would contrast that with our own situation, which is very often arm's-length: We have bidders, we take the low price, and there is a real gap.

Attending to "everything else"

SHAPIRO: You know, Ralph, you said something that to me goes right to the very heart of this issue: that things depend on "how groups work together." If we

applied that concept across the board, instead of worrying about just how good our science is at the moment compared to someone else's science, we'd be a lot farther ahead. I'd like to write an essay on this subject, with the title "Science, Technology, Economic Growth, . . . and Everything Else." That is, if we want to get economic growth out of new science and technology, we have to pay attention to what I call "everything else." And the everything else really could not be summarized better than by saying "how groups work together"—how we relate to each other, how we treat each other, and how we *trust* each other.

Being first in science doesn't mean that someone else can't capture the associated economic and social dividends through better implementation.

GOMORY: The natural tendency is to assume at first that the guys in your area are good and the other guys are bad. In my early years as director of research at IBM, my people would often come to me and say, "my thing is really much better than what 'they'—in development, or manufacturing—are doing, but they do not appreciate it, or they are committed to something else, or they are just plain crazy." But I found that when our scientists really understood what the other folks were doing—after they had worked with them on something, seen what they were up against—then they started to understand that those development and manufacturing guys were good guys too.

They live in a different world, though, and they have to abide by different rules. It's true that they didn't accept our "better" way of building the front end of a display, for example, but it is also true that we brought it to them when they were already 11 months into a two-year cycle to finish the product. There was no way that they could adopt our suggestions without slipping the product's timetable six or eight months, which was totally unacceptable.

SHAPIRO: I think there is another great dividend that comes from having different groups—in research, development, manufacturing, and so on—working together, and that is the important and entirely beneficial impact on the science agenda. Many people have the notion that scientists are separated from the rest of us—that they only march to the beat of some special kind of drummer. But history tells us that this is usually not the case. The best science happens when the agenda is informed by issues that bother all of us—the people in development and the people in manufacturing, for example. And needless to say, it produces work that in the competitiveness sense is much more relevant.

But while social and economic dividends can clearly flow from a better understanding of the natural world, we also have to look at this "everything else" category—things other than what is going on in the lab and in researchers' heads.

Two extremely important issues come to mind that affect our competitiveness and that in many ways are independent of our current capabilities in science and technology. One is the question of our overall economic policy: Are we getting an adequate amount of investment in our society or not? My own judgment is that our country has suffered in the past few decades because we're doing too much consuming and not enough investing.

The second issue has to do with education, and by that I mean primarily K-12. A lot of people are working in manufacturing who have high school educations; with modern technology, it's very important how good those educations are. Even if you don't know probability theory, you should still be able to use statistical process control in a manufacturing facility. But one of the things we are suffering from is that, by and large, our high school graduates can't do this, whereas some of our competitors have high school graduates who can.

Who's on first?

GOMORY: I'd like to go back to something discussed at the start. I think that we must better understand a very important distinction—between the economic dividends that come from basic science and the economic competitiveness that comes from being the *leader* in basic science.

I don't think there's a shadow of a doubt that

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scientific understanding has resulted in tremendous economic advance *for the world.* Basic research leads to understanding, and understanding enables people to do things that they couldn't do before. But there's a major difference between the global economic benefit from some new piece of scientific knowledge and its effect on the competitiveness of any particular country—including the country of origin. There may be many reasons why the basic research cannot be well appropriated locally. Meanwhile, the idea is out there, and whoever can grab hold of it to make something useful can enjoy its benefits.

In the modern world, which has well-developed companies everywhere that are capable of assimilating whatever is new and potentially useful, it's not clear that you have a large advantage by being in the country where an idea first arose. Moreover, industrial competitiveness depends on many factors, some of which we have already talked about—a rapid product cycle, working together, relations with your suppliers—which are critical even if you *are* doing well at appropriating the benefits of science.

So there are two important, but frequently unrecognized, links connecting basic research with industrial leadership: You do not have to be the science leader to be the best consumer of science; and you do not have to be the best consumer of science to be the best product manufacturer.

SHAPIRO: I basically agree with the distinctions you've made; processes are now getting sophisticated enough and changing often enough that as long as a country is a good consumer or implementer of science, it doesn't have to be in first place. But I increasingly get the feeling that it cannot be too far behind, either. If you're in 17th place, you probably can't compete.

GOMORY: Yes, it's hard to imagine that Nigeria, for example, will beat the United States in transistors, even if its companies have a very good work-together spirit. But it's quite possible to be "not first" in science and beat the United States handily, as long as the capabilities that matter are in the right places. One of Japan's great advantages, for example, is that a lot of its technical strength is in entities that are tied to industry or *in* industry, whereas America's scientific strength is pretty much vested in the universities, with a couple of companies thrown in. So even though Japan's universities compared to ours are scientifically weak—and they don't help so much in the idea-generation process—its industries function well in the appropriation process.

SHAPIRO: That's a very interesting point, and it calls into question whether it's in our country's long-term interests to have such a high proportion of scientific talent inside universities, as opposed to other establishments.

Why pull beats push

GOMORY: American companies have to do a better job of reaching out and getting what they need, which may mean more in-house scientific capability and whatever else it takes. I don't think you can put the burden on the universities to do it for them, although there is a lot of talk about that, because of the basic difference between "pull" and "push."

If people are building something as part of a development and manufacturing team, what they can accept depends a lot on what they've got. It depends on what tools they have, whether they accept square shapes or round, whether their engineers are familiar enough with any particular approach being proposed.

Now, you can have a great idea up in the university, and you can go to these product developers and say: "Look, I can make a better valve." But believe me, even if it *is* a better valve, the odds are overwhelming that they cannot accept it. Putting a better valve into their equipment may mean that they've got to change 43 tools, which will make them say "to hell with it."

On the other hand, if the people in industry are familiar with advances in science and technology, they can go out and pick the ones that they can accept—the ones that fit. That's the phenomenon of "pull." By contrast, it is very important not to assign to universities the responsibility for "push"—for transferring ideas into industry. I don't think they can do it. (I'm making a distinction, by the way, between a new idea and something that is established. My remarks here relate to improvements on an existing product. Universities can certainly help new ideas to get started, and they have a superb record in that area.)

SHAPIRO: Let me support the two points you're

making—that it may be desirable for firms to have more in-house capability in research and development than they currently have; and that "pull" really works most effectively—with an example from the agricultural chemical industry. A particular manufacturer was trying to tap into the next generation of insecticical chemicals—and given that the avoidance of toxic waste problems (from its existing product line) was a matter of life and death for this company, it was much more concerned than any university professor could ever be.

Company planners developed a concept that satisfied a bunch of different things they needed, and then they went out and looked for it, all around the world. They pieced together what they needed, based on what they found in four or five different labs in widely different spots. They had enough in-house scientific talent to understand the problem, formulate the concept, test it out with their marketing people and others who would be involved, and then pull from the world of science—in this case, from quite a few nations—what was required.

If we want to get economic growth out of new science and technology, we have to pay better attention to "everything else"—in effect, how groups work together.

GOMORY: What your example illustrates is that "pull" consists of people who know what they need going out and looking for it—and finding it—in a vast universe, rather than asking outsiders who don't know the company's situation to throw pieces at it. "Pull" is much more likely to succeed, moreover, because the burden of finding uses for research belongs not with universities but with the companies themselves.

But by and large, American companies are not doing a very good job in this area, whereas Japanese firms are quite successful at it. They have a different psychology about "not invented here." Not burdened with the Western notion that the important thing is to be the inventor, they are very relaxed about taking other people's ideas. The essential point, they believe, is to have a good product; that is what they are proud of. They will show you something and say: "Look at what I've got. I took this thing, that thing, the other thing"—they will name all the sources—"and here it is, the best product of its kind in the world." By contrast, I have known people in IBM who tended to be defensive about the fact that the original PC was put together using a lot of parts from other companies. If we had been Japanese, the thought would probably not have crossed our minds.

Science and math: Not for everyone

SHAPIRO: As we discussed before, while there is no necessity for us to always be first in science, we cannot be last. Even if we're quite willing to use other people's ideas, that alone requires considerable sophistication. Thus we've got to worry about the training of our industrial people, even of those who are just high school graduates.

But we have the problem that a growing proportion of our population, especially the minority population, simply is not participating in the technology side of our educational system. More and more, students are not taking science and not taking math. I wonder whether this education "deficit" will undermine our efforts, regardless of how much insight we gain on the competitiveness problem. Will we have the human capital necessary to man the system, even if we could design it right?

GOMORY: That's an interesting question, Harold. Everyone instinctively says that we've got to teach young people more math and we've got to teach them more science, but do we need to do so for everyone? I'm not sure. I am sure, though, that they've got to be able to read and write.

SHAPIRO: You'll settle for old-fashioned literacy, is that it?

GOMORY: Well, I would certainly say it's a prerequisite. Beyond that, I don't know. For one thing, I've never seen a survey that estimated how many people we actually need who are scientifically literate, in addition to people who can work together and write letters. It's more of a gut reaction on the part of scientists that

everyone should understand science in order to make informed political judgments. And I'm not convinced that it would help much there, so let's put that one aside.

Although I don't know how many people need to understand science, my guess is that it's a minority. What we really need, in my opinion, is to educate everyone in the three R's, which we clearly don't do well enough today. Then we need to devise strategies to identify those students who find science and math interesting or are amenable to learning about them.

Meanwhile, it's not clear to me that we would serve the nation by trying to jam science and math down everyone's throats. In fact, it may be counterproductive. When I was growing up, the high schools always taught algebra and geometry. But believe me, very few of the people who were taught all that knew what they were learning or ever used it again. Teachers argued that it was good mental discipline—they said the same thing about Latin—but for most students, the results were pretty negative.

Today in IBM, we find that there is a need at some of our manufacturing plants to teach technicians a bit of physics in order to do their work. Often, the biggest deterrent in this is math. People are frightened to death of math because they've had such bad experiences with it in school. Ironically, you could get a pretty good intuitive grasp of the physics with next-to-no math, but that would go against convention. In this case, that's the long way around.

SHAPIRO: You raise a very interesting point, Ralph. But don't you think we need more students who finish high school with at least some meaningful exposure to science and math?

GOMORY: If I had to make a guess, I would say yes. But I would also guess that the way to get them is not to try to raise the level of science and math education for everybody, which strikes me as very hard—especially in the short run—but to allow different tracks. Suppose, for argument's sake, that the number of people who now emerge scientifically literate from our educational system is 5 percent. Suppose further that we must double that—to 10 percent. It's a terrible task to try and raise the level of everyone's education when you only need to find the 10 percent of the people who are interested and wish to be taught.

Perhaps a more practical approach in the short run would be to improve a few selected schools—including some with heavy minority enrollments, in order to correct imbalances not based on competence. We could try to attract and keep good teachers there, and incorporate incentives for students to learn. But we should confine these actions to a relatively small number of schools, because only then could the program be feasible.

SHAPIRO: You know, it's quite extraordinary that a very small set of high schools in this country has produced most of its scientists and engineers.

GOMORY: Is that right?

SHAPIRO: Yes. I don't remember just what the number is, but it is quite small. Where something important is going on, it is often income-related, but often it is not; a lot of the rich schools are not in this set.

GOMORY: The smallness of that set suggests that doubling its size—giving us a still-small set—is something we can afford to do. We don't have to boil the ocean of the United States.

SHAPIRO: We could double that number not in any arbitrary or elitist way, but simply in a way that is open—for example, in magnet schools, where people with the appropriate motivation and capacity who wanted to take advantage of the opportunity could do so.

Not by science alone

GOMORY: Since we're talking about education, I cannot help but throw in something else. The United States is a market economy, but where in people's education are they taught how this system operates?

SHAPIRO: Let me connect that with something you said earlier—that it's important how we work together. The market system—driven by the profit motive, or self-interest, or whatever you want to call it—is really a very subtle form of cooperation. At its best, it is a mechanism for cooperation that generates productivity and efficiency.

GOMORY: I agree. But such ideas are rarely taught in

our educational system. Other countries are usually more rigorous in teaching their children the advantages of their economic systems.

SHAPIRO: Actually, I think some healthy skepticism may be in our best interest. But what may *not* be in our best interest is the belief that superiority in science alone—at the expense of "everything else"—will ensure this country's economic strength.

The lessons of history tell us otherwise. For example, it was not Britain's science and technology superiority that made it first in the Industrial Revolution. It was political stability, it was the society's concept of private property, it was decentralization of authority in British institutions. It was *not* that the British had better science than did Belgium and France. It is very, very seldom that a monopoly on science alone has produced a tremendous spurt in sustained economic and social dividends. Why is it that we do not read that lesson?

GOMORY: One reason is that the people doing the talking are often the scientists. And the distinction we were discussing earlier—between the economic benefits that derive from science and the competitiveness that being the *leader* in science does or does not bring—is often overlooked. Our very powerful scientific community, in my opinion, does great good for the world—not the United States alone, but the *world*. So as long as we're being cosmic today, maybe the time has come to justify science in a different and more appropriate way. Maybe we could, over the next 10 years or so, gradually transit into a system in which science—because it is good for the advancement of all humanity—would to a greater extent be fostered on a worldwide basis. Things such as the superconducting super collider, if they are to be done at all, could then be done internationally. Problem is, I don't know how to make that transition.

SHAPIRO: Neither do I. But at least we ought to have a certain amount of truth in advertising; we need to be straight about what it is that we are trying to accomplish. When we want to fund work in science that is meritorious for a wide variety of important reasons, we ought to be clear about what those reasons are, where the benefits are, and who will enjoy the benefits. We must avoid the frustration of having paid for all the science and watching someone else get most of the rewards.

What we need to do before anything else, however, is get the message out. Important people—not simply those who make up the government budget but principal players, say, in the IBMs and the school systems of the nation—should have a more informed idea about what is necessary if our country is to achieve leadership. Without any more money, they can make adjustments that will improve our economic competitiveness.

Meanwhile, we have to get rid of the attitude that government is our enemy. We must try to think of the government as an extension of ourselves for purposes that we cannot achieve by working separately. In my view, those purposes should include the development of decent public policies for encouraging investment rather than consumption, for promoting economic growth, and for establishing appropriate regulation (or, alternatively, avoiding overregulation). And despite our remarks about paying attention to "everything else," I am all in favor of even greater funding for science because that enables great things to happen.

However, the question an economist always asks is: Given limited resources, where are you going to put them? Great things can happen *wherever* you place your emphasis, so the challenge is to pick the areas of maximum impact. In order to achieve such impact, people have to start thinking somewhat differently. Any one person—even the CEO of Ford or the head of the Senate Budget Committee, for example—can't make enough of a difference. That will require some fresh insights from a whole lot of people. But the problem isn't difficult as it may appear. The debate doesn't have to be radically transformed, just sort of rotated a bit.

The CHAIRMAN. Thank you, Dr. Gomory.

Questions? The gentleman from New York.

Mr. SCHEUER. I enjoyed the testimony very much but I have no questions.

The CHAIRMAN. We have two gentlemen from New York and we have got them both confused. The Chair now defers to the distinguished gentleman from New York, Mr. Boehlert.

[Laughter.]

Mr. BOEHLERT. Thank you, Mr. Chairman.

Dr. Gomory, I would like to thank you for the common sense, down-to-earth testimony. It is so refreshing to have that.

In the cyclic process, what can government do to help accelerate the pace? If I am hearing you correctly, government is not at fault here; it is the private sector. They are not doing what they should be doing. Is it because of our antitrust laws? Is it because of our tax law? I mean is there something that we can be doing constructively to help in that area?

Dr. GOMORY. I think that is a very good question and I wish I had a stronger answer than I do for it. It is clear that it is a lot easier for the government to effect the introduction of new technologies than this process.

Mr. BOEHLERT. Excuse me. If I may, that is because we do so much better than the Japanese in terms of basic government investment in basic research.

Dr. GOMORY. Yes.

I think that there are a lot of things that can get in the way. I think that sometimes the antitrust laws get in the way. I myself lived through inflation, and let me tell you that—I am not an economist, so I am not testifying in the theoretical way—but I saw with my own eyes the devastating effect that inflation had on our trying to do things in a long-range way. In IBM we were able to persist, but it was very, very difficult. So certainly all the economic surround is one way that government can effect these things.

I think that removing legal constraints is another. It can only do good. How much good it will do I do not know. But it is the right way to go. And I think the other thing is that perhaps in our educational system we need to foster a greater awareness of this whole manufacturing process that is out there because too long, I think, the attitude toward manufacturing and even product development has been, well, that's for the lesser people. And in fact, in the U.S., manufacturing has really been considered a blue collar enterprise, and all the talented people are supposed to be scientists.

So we have developed a mindset which is reflected to some extent in our teaching and what we teach and so forth, which does not help us when we are trying to fight people who do see manufacturing as a scientific and technical challenge. They put talented people in it. They work on it systematically. And we have to learn to do those things. But your initial remark, I agree, it is mostly a company thing.

Mr. BOEHLERT. It is a cultural problem.

Dr. GOMORY. Yes, it is also.

Mr. BOEHLERT. My perception of corporate America—and I worked in management for a Fortune 500 company in my real life—how do we change so that they begin to take the long-term

view and think about something other than the next quarterly statement?

Dr. GOMORY. Mr. Boehlert, you are now pushing me beyond my knowledge here, how to change that. But I would say I am an optimist, not because I know how to change the American culture, but because from my point of view we can do a lot by changing just certain small microculture.

In other words, we have had the experience of taking a development team, putting it with a manufacturing team, saying design this damn thing so it is easy to manufacture, and seeing it happen and seeing it come out and seeing it competitive with imported products.

So you can do a lot without tackling the vast difficulties of changing the culture, the quarterly report orientation, the educational system. If just the folks in the process learn how to do that—and that is microcultural change—it is changing a development team of 80 or 90 people and a manufacturing team of a few hundred people so they approach their tasks differently.

The reason I am an optimist is, I think we can get a lot done by changing the habits of these relatively small work groups, not that we should not change the bigger thing, but that is a more horrendous task.

Mr. BOEHLERT. One last thing, Mr. Chairman, if you will indulge me. I happen to think the consuming public is rather sophisticated and you can not sell them a pig in a poke. For example, I think the reason—and this is only my opinion—the reason why the Japanese in the late '70s and early '80s surpassed us in the auto industry, for example, is because the Japanese made a better product.

Dr. GOMORY. I agree.

Mr. BOEHLERT. Not because they had better marketing or better research or anything else. They just essentially made a better product.

Would you agree with that?

Dr. GOMORY. Yes. And I would say that it was better because of better design for manufacture and better manufacturing techniques.

Mr. BOEHLERT. Thank you, Mr. Chairman.

The CHAIRMAN. Further questions? Connie? The gentlelady from Maryland.

Mrs. MORELLA. I am delighted to have heard your testimony, Dr. Gomory. I am curious. Do you believe that one of our difficulties in the United States is that we are putting too much money into research that goes into defense rather than domestic research?

I mean if we are looking at Japan, which generally becomes the country that we use for comparison, where they put less money, the government funds research to a smaller percentage than we do; nevertheless, almost none of it goes into the defense research.

Do you feel that we should alter it, if you will, putting too much into that? It is about one third.

Dr. GOMORY. Let me try and answer that. And then if you do not feel my answer is responsive, please tell me. Rather than comment on whether we are spending too much on the defense side, I would certainly say this: that their government is very effective in helping the introduction of new technologies.

They do organize consortia and things like that for the early stages of technology. We have all see them. We have seen the VLSI program, we have seen the Fifth Generation program, and so on. There is an endless list of them.

I do think they are very effective in organizing the starting phases of new technologies. In addition, their government labs are to a considerable extent focused on problems of industry, like they have a ceramics-oriented significant government lab. So they do spend money and they do spend it intelligently in helping give their industry a head start. They definitely do that.

Now, could our government do that better? Yes, I believe it could. I would rather speak to that point, we could do better, than to the defense question.

Mrs. MORELLA. That gets into, you mentioned the idea of education. I would agree with you that we think that manufacturing is just much too mundane for us to be involved in. And I know the Japanese, again as an example, do a lot more with dignifying and elevating this whole concept of getting a new product, manufacturing, so that is something that we should all be much more attentive to and try to do something about.

But I wonder also with regard to our support of the consortia for product development, should we be asking that industry work out some kind of a repayment maybe through a royalty on gross sales or something? Would that stimulate it? Should we be asking for something back?

Dr. GOMORY. A repayment to government for helping consortia you mean?

Mrs. MORELLA. Right. For instance, in terms of high definition TV or whatever.

Dr. GOMORY. I do not want to talk about things I do not know about. So I think that if I may say so, is sort of a political question, whether they should repay, or whether the satisfaction should just come that the country is better off. I do not feel I am an authority on that.

I do think, though, that consortia can help, but I think there are natural and harder areas for them to help. For example, I was chairman of a committee that recommended that we do form a consortium to try and advance high-temperature superconductivity. And we are trying to get such a thing organized. Now, to my mind, that is a natural area for consortia. Let me explain why.

There are also, in my opinion, areas where it is more difficult. I will mention that, too. High-temperature superconductivity is a new technology. There is no big industry out there doing it. Furthermore, there will not be, in our judgment, for many years because it will take many years to get anything practical out of this.

It is therefore an area in which industry has a lot of trouble investing, because they are investing for things that are perhaps seven years away, optimistically, and may never happen in addition. Well, that kind of investment competes with difficulty for funds within a company.

On the other hand, you do not want to leave that entirely to universities and basic research because they will not understand what the applications, even the long-range applications are; because you

have got to be a company which might some day use this to understand all the wrinkles of the application.

That is a natural, in my opinion, for a consortium which combines the basic research capability, say, of a university or government lab with companies who understand what ultimately this stuff might be used for. In other words, you put those pieces together and for the first time you have an organization which has an understanding of application and an understanding of the science—a natural position for consortium.

Second, you can put together consortium, 50 or 100 people, and they are an appreciable force, because you are talking advanced technologies that are not yet industries, you are talking small numbers. So if you can fund 50, 100 people, you are a major player in an advanced technology like high-temperature superconductivity. So you can create something that is important.

Now let us take the opposite extreme. Supposing you are trying to get into something that is manufacturing and in a very large established industry, and you want to have an effect with a consortium. You have got an industry with, say, 80,000 people working away at it and you put together a consortium of a few hundred, it is only a limited effect it can have.

So I think there is a very natural realm for consortia in the introduction of new technologies. It is a lot easier to see their role, a lot harder—I'm not saying that they can not do good, but probably not as much good, when you are trying to deflect an industry that is already going along at many, many billions of dollars a year.

Mrs. MORELLA. I appreciate your answer. I was actually thinking that you could encourage more federal funding if you could ultimately see a benefit for business, but also some kind of return to government, too.

Dr. GOMORY. I am sure you are right, that that would be an incentive.

Mrs. MORELLA. Thank you, Dr. Gomory. Thank you, Mr. Chairman.

The CHAIRMAN. The Chair recognizes the gentleman from Tennessee, Mr. Tanner.

Mr. TANNER. Thank you very much, Mr. Chairman.

Dr. GOMORY. I was at Dyersburg State College last Friday night in my district down in Tennessee, and they showed a movie, "Losing the Future," an ABC special.

Did you see that?

Dr. GOMORY. No. I am sorry, Mr. Tanner, I did not see that.

Mr. TANNER. It touched just on the very points that you made in your testimony. I wish you had been on the show because you did a better job of explaining it, quite frankly, than the ABC News did. I hope they are not here.

Mr. BOEHLERT. At less of a fee, too.

Mr. TANNER. Right.

Dr. GOMORY. I am open to suggestions, of course.

[Laughter.]

Mr. TANNER. It has been suggested from time to time in Tennessee where I am from, and also here, that some of our product liability laws, the legal ramifications of new products, in some way inhibit the manufacturing or the bringing to fruition a scientific idea

to the marketplace in this country. Does that argument have credibility in your opinion?

Dr. GOMORY. Mr. Tanner, I have not had much direct experience with that myself because I do not think there has been a lot of product liability issues around computers. I can cite one example when what you said certainly did apply, and that was some years ago. We were having a lot of problems with the introduction of terminals—with their cathode ray tubes or TV screens—because of the feeling that the radiation from them might harm people. We never could find any trace of that.

But, yes, that was certainly an inhibiting effect. Just the possibility of people seeing that was an inhibiting factor.

Mr. TANNER. I thank the Chair.

The CHAIRMAN. I thank the gentleman. The Chair recognizes the gentleman from California, Mr. Campbell.

Mr. CAMPBELL. Thank you, Mr. Chairman, and thank you very much for holding these hearings. I have two questions. I will try to be brief, Dr. Gomory.

First of all, your unwillingness to testify in areas you do not know anything about disqualifies you from running for office.

My two questions: First, as you may know, I have been working in a bill to create an antitrust exemption to allow consortia to occur, to allow American firms to pool their efforts. If we were to have that sort of an antitrust exemption, I am wondering whether we would need the federal funding. In other words, if we got rid of the federal government structural barriers to consortia, would we have a better chance at making progress without even the funding? Could you speak to that?

Dr. GOMORY. Mr. Campbell, certainly doing that would be a plus. Anything to remove these barriers, definitely a plus. I do not think I can give an across-the-board answer because there might be cases where that was the only plus where that was needed, and there might be cases in which money was also important.

For example, I think in the high-temperature superconductivity thing, there is not much worry about antitrust, but money does seem to be important. So I think you will find there are cases of both types. But I would certainly say we would be grateful for any help we can get.

Mr. TANNER. I appreciate the answer.

And one last question: I thought your insight in your testimony was exceptional. You told us about cyclical development. IBM is rather unique in the information science area in being so vertically integrated. You are a captive manufacturer of your own chips. You are not a merchant manufacturer.

This vertical integration interests me, and I wonder if, as a scientist, you could speak to whether your ability to work in a vertical stream in your view is one of the significant advantages and explanations for IBM's competitive edge.

Dr. GOMORY. I think it is a very significant advantage to us because when we develop our own semiconductors, for example, and that I think is a subject you would be familiar with because of the district—we can design them specially to go with our computers, and we definitely get a competitive edge from that.

The second thing is that when the semiconductor world goes up and down, which it does, our semiconductor manufacturing does not go up and down. It is capable of having a long-range plan because it knows we need the damn things.

Mr. CAMPBELL. I thank you once again for that exceptionally good testimony. Thank you, Mr. Chairman.

The CHAIRMAN. The Chair recognizes the gentleman from Connecticut, Mr. Shays.

Mr. SHAYS. Thank you for your testimony. We had a very interesting hearing yesterday as well, and probably one of the most interesting hearings I have ever attended in my 14 years in politics.

Yesterday they said we do not use our technology. One of the witnesses talked about how we produce science, but we do not eat it, we do not consume it. I am wondering if I draw those same parallels to your comment of the ladder process versus the cyclical, you are basically saying in so many words the same thing? I mean is making a quantum leap in technology and using it, but in a superficial way, the same thing as not taking advantage of our technology?

Dr. GOMORY. I do not think I can give quite a yes or a no answer. In fact, you might almost say that we have been pretty good as a country in using our scientific breakthroughs in the early stages. Take the transistor, the all-time breakthrough of our century perhaps. We really did use it. And we built an industry on it. We built more than one.

Once that became more mature, we did not excel in pulling in the new ideas and their rapid execution to keep that engine running full speed.

Mr. SHAYS. One of the witnesses described that organizationally, we do not have this consuming machine. He described certain companies that develop and implement and constantly revise and perfect, and he said we do not have that kind of—I got a very pessimistic view because—and this is what I am leading to—you basically say you are optimistic because it is a microdecision.

The message I got from some of the speakers yesterday was that it is more than just micro. There is a whole network that is not in place anymore in a lot of our major companies in certain industries. So there was a more pessimistic view.

Dr. GOMORY. I can understand that people would be pessimistic. Having actually seen this happen, I am more optimistic because I have seen it go.

Mr. SHAYS. I am just wondering if you are not, though, a science-consuming machine in your own company; in other words, that maybe you represent in some cases what we want to see.

Dr. GOMORY. I would like perhaps to shift away from the notion of science-consuming because I think that within that phrase are embedded certain wrong images. One of the things that we observe with the manufacturing-development cycle is that the speed of the cycle—which is not a question of whether it consumes science or not—it is a question of how tightly can manufacturing and development people work together—is terribly important.

So in some sense, I guess I would believe that this picture that we generate science and we do not consume it is too superficial a picture and it does not allow for the tremendous role played by the

manufacturing and development people. Things like design for manufacture are not necessarily consuming science at all. If we design, as we did, a new printer—it is a mechanical object, it just drives pins into a ribbon, that kind of stuff—very little science was consumed either in the thing before it was redesigned or the thing after it was redesigned. But the fact that it was designed to be manufacturable was decisive.

So I think that the science-centered notion that we generate it but we do not consume it is sort of the wrong model for a mature or semimature industry. There is a lot of execution involved.

The CHAIRMAN. The gentleman will have to suspend because we are on the second call and we have only got five minutes. The vote is on the rule for the Department of State authorization. H. Res. 126.

Will the members please return immediately so we can continue and go on from there?

[Recess.]

The CHAIRMAN. The committee will come to order. When we broke to go and vote, we were having some questioning coming from the distinguished gentleman from Connecticut. The Chair recognizes the gentleman from Connecticut.

Mr. SHAYS. Thank you.

In your statement, in general I got the feeling from reading parts of it that you said the researchers and the product engineers are too separated from the manufacturing process. Is that a fair comment to make?

Dr. GOMORY. Yes.

Mr. SHAYS. I kind of compared that to the testimony we had yesterday where we talked about our being a consuming machine of technology and not having that in this country. I notice from one of the articles that has you and Harold Shapiro—I do not know if it is his quote or not, it is just a highlight—it says, "Being first in science does not mean that someone else can not capture the associated economic and social dividends through better implementation."

Now, the message that I got from yesterday was that we have some very serious flaws in this consuming machine that we have that give me a pessimistic feeling. Why do you think it is just a little tinkering and that will take care of it?

Dr. GOMORY. Mr. Shays, that is a very good point. If you will permit me, I will just be very concrete and give an example which I think will convey a lot more than any abstractions which I can possibly give.

We had the following experience. If you are at all familiar with personal computers, you know they are often accompanied by printers. These are called dot matrix printers, but whatever they are, they make that pounding sound and they print. Now, that thing, it is a mechanical contrivance. The printing is done by little metal needles that are driven forward by magnets. The whole thing inside is mechanical, with a limited amount of electronics.

We did not have a competitive product. And when we had our successful personal computer, they were selling every printer known to man, but not IBM's along with them. And most of those were imported from Japan. Our people did not know how to make

a competitive printer. They took apart some of the competitive printers and, to their astonishment, they found that instead of having about 160 parts, they had a lot less. Very few screws, very few springs, as mundane as that.

Our development team, instead of focusing on something that would make very nice characters and would last through 10 million impacts, all of which you have to do, they also took a very arbitrary and very advanced goal. They said 60 parts. Our new one is going to have 60 parts and it is going to have no springs and it is going to have no screws, and it is going to snap together in a vertical direction. In other words, assembly will be simplified because it will not be pushing in from the sides or up from the bottom. Everything snaps from the top.

They took that as their goal. They did not quite make it. I believe they ended up with something like 62, and it may have been one screw or one spring, I can not remember which. It did not matter. A person could put the thing together in three or four minutes. That went on to become the biggest selling printer of that type in the United States and it outsold the competition which was from abroad.

That kind of a transformation, having seen it—which did not have an awful lot to do with science, as you can see from my description, but it did have to do with designing for manufacturing, having the manufacturing folks in it—is a very extreme and simple example of the sort of thing I am talking about.

Mr. SHAYS. Just one last question. What is the logic that says that we are going to see ourselves become more of a service provider rather than a manufacturing provider? I have accepted it, and I thought later on, why?

Dr. GOMORY. Well, you and I are in the same boat now. I do not understand that one either. I think we have to manufacture.

Mr. SHAYS. Thank you. Thank you, Mr. Chairman.

The CHAIRMAN. Any further questions? The gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. Our manufacturing base is now about 20 percent of our economy, is it not? I mean I have heard a lot of talk here in the last few days about how we are losing our manufacturing base and it is about the same percentage as it was 20, 25 years ago, is it not?

Dr. GOMORY. I really do not have those statistics.

Mr. ROHRABACHER. Yes, it is. Statistics pointed it out. It is just that the manufacturing has gone from big manufacturers into moderate sized manufacturers.

I am sorry. I have been running in and out of hearings all day, so I am not sure whether you actually stated or whether it was in your article, but you mentioned about successful companies having a two-year application time. Is that something I read in your article here?

Dr. GOMORY. I probably said that it was an advantage to you. If you had a two-year cycle and your competitor had a three, it was a very substantial difference to you.

Mr. ROHRABACHER. So that a successful company should have a two or three-year application of technology upgrade or new product introduction; is that right?

Dr. GOMORY. The actual cycle will be different, depending on the complexity of the product. The point I was making, I think, in that article is that you have got to be better than your competitor. If he's three, you better be two, or at least not longer.

Mr. ROHRABACHER. But at the pace of new technology, a successful company should be expecting to put these new upgrades in technology or new product on the line within a very short period of time; right?

Dr. GOMORY. Yes.

Mr. ROHRABACHER. So in terms of our falling by the wayside or some of our companies not being competitive has nothing to do with long-term research programs that we are investing in, but basically application.

With that said, you would say that the management structure of our corporations is probably—would you say that for the corporations that are unsuccessful, it has much more to do with management structure than long-term research?

Dr. GOMORY. Let me give you the best answer that I can. I have tried to distinguish between the effect of long-term research, what I called the ladder process, which has to do with the initial phases of a new industry. In that case, it is the dominant fact.

Once we get beyond that stage, then the dominant features are other things. And they are how quickly you implement existing technology, and certainly how you are organized to do that, has a very large management component. And in those stages of the more mature industry, which is what most industries are most of the time, certainly management is more important than long-range basic research.

Mr. ROHRABACHER. It is just that we heard yesterday, the idea that corporations' investment in long-term research makes them vulnerable to short-term takeovers and people are actually discussing, seriously discussing legislation that would protect these companies, making their management even more comfortable in the name of letting them having long- term research. And what I am hearing from you is that it is actually the fact that their structure, that these companies, these very people who would be protected by such legislation are not structuring their company and not managing their company in a way to take advantage and implement and apply these new technologies that are becoming available.

Dr. GOMORY. Well, I really do not want to be put in the situation of coming out against long-term situation, to which I have devoted a very large portion of my life.

I have always found it quite difficult to convince people that there is more than one thing that has to be done. People like to have one. Now, if you have a company that is having trouble competing in printers like we were, the more important thing to be done at that time is to fix the thing you are having problems with. And that was short term and it was design for manufacture and things like that.

On the other hand, if that is the only thing you ever do, then you will never get a new technology printer. And when dot matrix printers give way, as they are giving way, to xerographic printers, to inkjet printers and so forth, you will not be a player.

So my view would be more that you really want to do both. They have an impact on different time frames. Neither one will substitute for the other. In other words, you could make the error of saying, hey, it is all a question of advanced technology and basic research. Not so.

You could make the error of saying hey, it is just a question of design for manufacture. Not quite so. That will help you this year and next year.

Mr. ROHRABACHER. What I am hearing from you and a witness yesterday was that it is the application that is the problem and not the long-term research and finding new product. And that lack of application suggests to me a management problem. And by protecting management from takeovers, you are actually making that same management more comfortable.

Dr. GOMORY. If I may try and refine this a little bit, I think you have a very good basic point. But, see, the word "management" is very, very sweeping because management means both the activities of the CEO who is worried about a quarterly statement and it means the activities of a guy who has got a team of 50 that is supposed to design the printer.

Now, my remarks were really aimed at the second category, not the CEO. I am saying you look at the manufacturing and the development teams and they can make a difference right down there. That is management, but it is not the kind of let us defend against a takeover kind of management. There are both kinds. I am really talking in the small.

Mr. ROHRABACHER. Thank you, Mr. Chairman. I appreciate it very much.

The CHAIRMAN. I thank the distinguished gentleman. If there are no further questions, Dr. Gomory, we want to thank you very much for being with us this morning. We appreciate your input to our efforts here.

The next two witnesses we have scheduled here, we are going to combine them because we are behind schedule. Dr. Herbert H. Woodson who is the Dean of Engineering, University of Texas at Austin, Texas. That is on Energy Research. And Materials Research is Dr. Pravine Chaudhari, Co-Chair of the Academy of Sciences Study "Materials Science and Engineering for the 1990s," and Vice President of Science, Thomas J. Watson Research Center, IBM Corporation, Yorktown Heights, New York.

We want to welcome both of you to our hearing this morning and thank you for your patience and indulgence. Your statements will appear in full in the record and you either can do your statement in full or you can summarize, whatever you think is best.

The Chair recognizes Dr. Woodson.

[The biographical sketch of Dr. Woodson follows:]

HERBERT H. WOODSON

Dr. Woodson holds the titles of Dean, College of Engineering, Ernest H. Cockrell Centennial Chair in Engineering, Dean's Chair for Excellence in Engineering, and Director, Bureau of Engineering Research, The University of Texas at Austin.

Herbert H. Woodson graduated from high school in Lubbock, Texas, served in the U.S. Navy during World War II, and then attended the Massachusetts Institute of Technology where he received his Bachelor of Science and Master of Science degrees in 1952, and Doctor of Science degree in 1956, all in Electrical Engineering. He served as a faculty member in Electrical Engineering at M.I.T. from 1956 to 1971, holding the position of Philip Sporn Professor of Energy Processing from 1967 to 1971. He was the founder in 1968 and first Director of the Electric Power Systems Engineering Laboratory at MIT.

In 1971 he joined the faculty in Electrical Engineering at The University of Texas at Austin. From 1971 to 1981 he served as Chairman of the department, from 1974 to 1988 he was Director of the Center for Energy Studies, and from 1982 to 1988 he was Director ad interim of the Center for Fusion Engineering. From 1980 to 1982 he was Texas Atomic Energy Research Foundation Professor of Engineering, and since 1982 he has occupied the Ernest H. Cockrell Centennial Chair in Engineering. He served as Associate Dean for Development and Planning in 1986-87, served as Acting Dean of Engineering from September 1, 1987 to July 5, 1988, and on that date he was appointed Dean of Engineering.

Dr. Woodson is the co-author of two textbooks, the holder of five patents, and the author of numerous technical articles. He has been a consultant for a number of companies and has served on several advisory panels for the government. He served as Vice Chairman of the Texas National Research Laboratory Commission until 1988 and was appointed to membership on the Texas Scientific Advisory Council in 1988. He served from 1983 to 1986 as Chairman of the Energy Engineering Board of the National Research Council and he currently serves as Chairman of the Advisory Council of the Electric Power Research Institute. He is a member of the National Academy of Engineering, a Fellow of the Institute of Electrical and Electronics Engineers, Past President of the Power Engineering Society of IEEE, a Registered Professional Engineer in Texas and Massachusetts, and a member of a number of professional and honorary organizations. In 1978 he received the Power Engineering Educator Award from the Edison Electric Institute, in 1984 he received the Nikola Tesla Award and a Centennial Medal, both from IEEE, and in 1988 he was named Engineer of the Year by the Texas Society of Professional Engineers.

Dr. Woodson has been active in community affairs, having served three years on the Board of Directors of the Austin Chamber of Commerce and five years as a member of the City of Austin Electric Utility Commission.

Dr. Woodson was born April 5, 1925, in Stamford, Texas. He married Blanche Sears of Rockport, Massachusetts, in 1951 and they have three sons and two grandchildren.

STATEMENT OF DR. HERBERT H. WOODSON, DEAN OF ENGINEERING, UNIVERSITY OF TEXAS, AUSTIN, TEXAS.

Dr. WOODSON. Thank you, Mr. Chairman and members of the committee. I am honored to have this opportunity to give you my views on the R&D needs in energy and the role that university R&D should play in helping to satisfy those needs.

My more complete thoughts are contained in the written testimony I submitted. To be brief, I am going to stay with my summary testimony, to give you my major conclusions and recommendations, to make sure I hit all the points I wanted to hit, and I will be happy to elaborate on any of the points you wish me to later.

First of all, let me just say in summary, I am of the opinion that the U.S. energy supply for the next 100 years or so—and I mean by that from 50 to 150 years—will come mostly from oil, gas, coal and uranium, with small contributions from hydro and other solar-based sources, from industrial and municipal wastes, and from geothermal energy.

I believe that energy supply R&D funding should be dedicated both to improving the economics of our primary sources and lessening their environmental impacts, and to the development of long-term options like breeder reactors, fusion, and solar photovoltaics.

First of all, we need to increase our domestic supply of oil by developing technologies to operate better in deeper offshore waters and in Arctic environments to discover and produce from new reservoirs, and we need to undertake active research and development to increase the recovery of oil from already discovered reservoirs.

The domestic supply of natural gas will be enhanced by the success of R&D for both discovery and production of new oil reservoirs and enhanced recovery of oil from old reservoirs. In addition, R&D needs to be done on the production of natural gas from deeper formations, from tight sands, from coal deposits and from geopressure, geothermal resources.

In order to more effectively use our very large domestic reserves of coal, we need to continue a vigorous R&D program on clean coal technologies. It is my belief that molecular biology and biotechnology may be the best route to clean coal technology for several purposes that have a chance of being economic. And I believe that nuclear fission is essential to the world as a major energy source that can supply electricity in the safest, most economical and least environmentally intrusive way of all the alternatives.

Now, on the topic of reactor types to produce energy, there is considerable talk these days about inherently safe reactors that will guarantee the safety of nuclear plants. I do not agree with that line of thinking. A nuclear reactor, even an inherently safe one, poses two fundamental dangers that must be dealt with.

First, a reactor core is typically supplied with a three-year supply of fuel. If energy is released too rapidly, a serious accident can occur.

Second, as the fuel is consumed, there is a buildup of radioactive fission products and actinides that must be contained. I believe the currently used lightwater reactors have proven that they provide adequate protection from both dangers and I recommend continued

R&D on lightwater reactors to improve their durability and reliability and to reduce their operating and maintenance costs.

I also recommend that R&D be continued on the high- temperature gas-cooled reactor as a source of high- temperature process heat, and on the breeder reactor as a long-term option.

Now, it is likely that geological isolation of radioactive wastes will be needed as an interim measure and possibly as a long-range measure for dealing with high-level radioactive wastes safely and economically. As a consequence, it is fitting to continue research on long-term migration and chemical reactions that can occur with radioactive wastes in geological formations.

But I also believe that research should be done on transmutation of radioactive wastes to reduce or eliminate the need for their long-term geological isolation. Now, in my opinion, the U.S. fusion program, as currently planned, in which information to be developed on the basis of which industry can make choices about fusion power plants, is doomed to failure, independent of the funding level.

I recommend that the mission of the program be redefined as a research program directed to the production and scientific study of controlled fusion, and that potential applications be considered only after controlled fusion has been produced experimentally and understood reasonably well scientifically.

In such a restructured and reoriented fusion program, attention should be given to the least expensive ways of experimentally producing fusion for scientific study, including high-field magnetic confinement, muon-catalyzed fusion, and the so-called cold fusion that has been recently reported from Utah. I feel confident that controlled fusion can be produced successfully, but I predict that the early commercial applications of fusion will likely not be for energy supply.

I feel that the only solar energy concept worthy of substantial further research and development is photovoltaic conversion. Now, an energy source that is used currently and whose use should expand is industrial and municipal wastes. Many of these wastes have significant energy content and their disposal is a problem. Their use as energy fuels, usually through combustion, can reduce their volume substantially. I believe that R&D should be supported on ways of extracting useful energy, limiting environmental impacts, and safely disposing of the wastes that result.

Now, I believe we must continue R&D on the generation, transmission, and distribution of electric energy. The fraction of our energy supplied as electricity has grown steadily over the years, and it appears that this growth will continue both because electricity is so convenient and versatile as an industrial, commercial and residential energy source and because two of our major energy sources—coal and uranium—are most conveniently and economically made available in the form of electric energy.

Research and development are needed to make our electric generating plants operate more economically and more reliably, with longer service lives, and research is needed to resolve whether or not electromagnetic fields and transmission and distribution lines pose threats to humans, animals, or plants. And research is needed to explore how best to deliver electricity over the longer term.

Power semiconductor electronics and high-temperature superconductivity can both have major impacts on how we generate and deliver electricity, and our R&D should address their uses.

The Electric Power Research Institute provides most of the funding in this country for R&D on electric energy generation, delivery and use. I am of the opinion that the current level of funding is inadequate for the need and should be increased, possibly by augmentation with federal funds.

We need a vigorous R&D program on end use technologies in all sectors—industrial, transportation, and residential and commercial. Work is needed especially in the industrial sector to keep our industry globally competitive.

The Gas Research Institute supports end use research and development on gas-powered systems, and the Electric Power Research Institute supports R&D on electric power systems. Their efforts may well need to be augmented.

Now, the final topic I want to cover is the rule of university-based R&D in creating the new wealth, R&D funding in the 1990s. In my view, university-based research plays two roles. First and most important, it produces well- educated graduates who will make their contributions to a better world, and it is my opinion that we are not now producing enough of those. Now, the more relevant the research that the students and their faculty are involved in, the better prepared they will be to contribute after graduation.

The second role of university-based research is to produce new and innovative ideas. Graduate students are generally very bright, highly imaginative and, very important, they are unencumbered by current practice and conventional wisdom. They are usually full of new ideas, some of which are good and some of which are not. The academic environment is especially conducive to the generation and examination of new ideas, and through these activities major benefits can accrue.

Because of the nature of an academic environment and particularly the relatively short residence time of students and the demands for classroom teaching duties of the faculty, not all R&D projects are suitable for a university setting. In particular, applied research projects with tight schedules and short deadlines and very large development projects are not appropriate for most universities.

That concludes my formal summary. I thank you for the opportunity, and I will be happy to answer any questions any of you may have.

[The prepared statement of Dr. Herbert H. Woodson, plus the biographical sketch of Dr. Chaudhari follow.]

SUMMARY TESTIMONY

by

Herbert H. Woodson

April 12, 1989

Mr. Chairman and members of the Committee on Science, Space, and Technology, I am Herbert H. Woodson, Dean of Engineering at The University of Texas at Austin. I am honored to have this opportunity to give you my views on the R&D needs in energy and the role that university R&D should play in helping to satisfy those needs. My more complete thoughts are contained in the written testimony I submitted. In the brief time I have I will summarize my major conclusions and recommendations and I will be happy to elaborate on any points you wish me to.

In summary, I am of the opinion that the U.S. energy supply for the next hundred years or so will come mostly from oil, gas, coal, and uranium, with small contributions from hydro and other solar based sources, from industrial and municipal wastes, and from geothermal. I believe that energy supply R&D funding should be dedicated both to improving the economics of our primary sources and lessening their environmental impacts and to the development of long-term options like breeder reactors, fusion, and solar photovoltaics.

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continued R&D on light water reactors to improve their durability and reliability and to reduce their operating and maintenance costs. I also recommend that R&D be continued on the high-temperature gas-cooled reactor as a source of high-temperature process heat and on the breeder reactor as a long-term option.

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In my opinion the U.S. fusion program as currently planned, in which information is to be developed on the basis of which industry can make choices about fusion power plants, is doomed to failure, independent of the funding level. I recommend that the mission of the program be redefined as a research program directed to the production and scientific study of controlled fusion and that potential applications be considered only after controlled fusion has been produced experimentally and understood reasonably well scientifically.

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An energy source that is used currently and whose use should expand is industrial and municipal wastes. Many of these wastes have significant energy content and their disposal is a problem. Their use as energy fuels, usually through combustion, can reduce their volume substantially. I believe R&D should be supported on ways of extracting useful energy, limiting environmental impacts, and safely disposing of the wastes that result.

I believe we must continue R&D on the generation, transmission, and distribution of electric energy. The fraction of our energy supplied as electricity has grown steadily over the years and it appears that this growth will continue both because electricity is so convenient and versatile as an industrial, commercial, and residential energy source, and because two of our major energy sources, coal and uranium, are most conveniently and economically made available in the form of electric energy. Research and development are needed to make our electric generating plants operate more economically and more reliably and with longer service lives. Research is needed to resolve whether or not electromagnetic fields from transmission and distribution lines pose a threat to humans, animals, or plants, and research is needed to explore how best to deliver electricity over the long term. Power semiconductor electronics and high-temperature super-

conductivity can both have major impacts on how we generate and deliver electricity and our R&D should address their uses.

The Electric Power Research Institute (EPRI) provides most of the funding in this country for R&D on electric energy generation, delivery, and use. I am of the opinion that the current level of funding is inadequate for the need and should be increased, possibly by augmentation with Federal funds.

We need a vigorous R&D program on energy end-use technologies in all sectors--industrial, transportation, and residential and commercial. Work is needed especially in the industrial sector to keep our industry globally competitive. GRI supports end-use R&D on gas-powered systems and EPRI supports R&D on electric-powered systems. Their efforts may need to be augmented.

The final topic I want to cover is the role of university-based R&D in "Creating the New Wealth: R&D Funding in the 1990s." In my view, university-based research plays two roles. First, and most important, it produces well-educated graduates who will make their contributions to a better world. We are not now producing enough of those. The more relevant the research that they and their faculty are involved in, the better prepared they will be to contribute after graduation. The second role of university-based research is to produce new and innovative ideas. Graduate students are generally very bright, highly imaginative, and unencumbered by current practice and conventional wisdom. They are usually full of new ideas, some of which are good and some of which are not. The academic environment is especially conducive to generation and examination of new ideas and through these activities major benefits can accrue.

Because of the nature of an academic environment, and particularly the relatively short residence time of students and the classroom teaching duties of the faculty, not all R&D projects are suitable for a university setting. In particular, applied research projects with tight schedules and short deadlines and large development projects are not appropriate for most universities.

That concludes my formal remarks. I thank you for the opportunity to give my views and I will be happy to answer any questions you have.

TESTIMONY

OF

HERBERT H. WOODSON, DEAN

COLLEGE OF ENGINEERING

THE UNIVERSITY OF TEXAS AT AUSTIN

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

APRIL 12, 1989

TESTIMONY

Mr. Chairman and members of the Committee on Science, Space, and Technology, I am Herbert H. Woodson, Dean of Engineering at The University of Texas at Austin. I am honored to have this opportunity to give you my views on the R&D needs in energy and the role that university R&D should play in helping to satisfy these needs.

To put my views in perspective it will be useful to review the sources and technologies currently used to fill our energy needs, and problems that currently exist with these sources and technologies, before describing what I think the R&D needs are to provide us with the sources and technologies that can take us in an evolutionary way from where we are to a brighter future.

In approximate terms, we currently get over 40 percent of our energy from oil and roughly half of that is imported. We get over 20 percent each from gas and from coal with roughly 6 percent from uranium, 4 percent from hydropower, and one-third of a percent from other sources including geothermal, wastes, and solar. In my view this mix has resulted primarily because of relative economics and availability of resources and technologies. Our experience of the past two decades has shown us that these characteristics can change over time, often dramatically.

Each of the sources and technologies we use has problems that concern us. For example, the fact that we import so much of our oil poses a national security problem. The combustion of all types of fossil fuels produces carbon dioxide that is thought to contribute to the greenhouse effect. Combustion of fossil fuels produces other gases such as sulfur dioxide and oxides of nitrogen depending on the composition of the fuel and the combustion conditions. These gases can contribute both to acid rain and to the greenhouse effect. The use of fossil fuels for transportation and power generation has caused air quality in some large urban areas to be unacceptably low. Combustion of coal produces solid wastes in the form of ash and scrubber sludge that must be handled and stored safely. Use of thermal energy to generate electricity produces waste heat which is discharged, often into lakes and rivers.

The production and transportation of fuels has posed problems of health, safety, and environmental impacts. For example, coal miners have suffered from black-lung disease, we have coal mine accidents that kill and injure miners, we have accidents in oil and gas exploration and production, we have problems with uranium mine tailings, and we have oil spills.

There is public concern about the safety of nuclear power plants and how radioactive wastes are to be handled and isolated. Hydroelectric projects require flooding of acreage for lakes which causes public concern.

The transmission of electricity by overhead power lines from remote generating sites to load centers causes concern about effects of electromagnetic fields on humans, animals, and plants.

In considering the energy sources we are likely to use in the future we must consider the size of the resource available domestically and the cost of extracting, delivering, and using that resource including the cost of meeting environmental standards. In my view the energy sources that have a

chance of large-scale use because of the size and domestic availability of the resources are: oil, natural gas, coal, oil shale, tar sands, uranium, deuterium, and solar. I will discuss each of these resources in terms of its size, availability, state of the technologies for use, relative economics and environmental impact, and the R&D needs to improve the status of that resource as a viable alternative for the country.

Oil is a major energy source now and, in my opinion, it will continue to be indefinitely, primarily because I see no viable alternatives for a large-scale transportation fuel. Air quality in large urban areas may become so poor that it is necessary to ban hydrocarbon burning vehicles from them, in which case several alternatives of hydrogen- or electric-powered vehicles, to be discussed later, may be considered. Otherwise, I see no alternative to liquid hydrocarbons for long-haul trucks, trains, cars, and airplanes. Whether or not oil continues to be used for stationary energy applications (primarily for industrial applications and home heating) depends on relative economics including those associated with making the environmental impact acceptable.

A very large amount of oil has been discovered and produced in this country but domestic production has been declining for a number of years and continues to do so. In my opinion R&D is needed to improve the techniques for finding new reservoirs that will generally be of smaller size and at greater depths than before and in the more hostile environments of deeper waters offshore and in arctic regions. It is my understanding that an increased rate of discoveries can reduce but not reverse the decline in domestic oil production--a fact that must be recognized and dealt with by policy makers.

A second source of domestically produced oil is that left behind in already discovered and produced reservoirs that cannot now be produced economically. It is estimated that of the more than 300 billion barrels of unrecovered mobile and immobile oil present in existing reservoirs, as much as 100 billion barrels of this remaining oil can be recovered at intermediate oil prices through improved geoscientific understanding of the distribution and occurrence of this oil resource base and development of advanced, cost-effective extraction process technologies. The Geosciences Institute, a consortium of leading national universities and state research agencies with established oil and gas recovery research capabilities, has been established by the Department of Energy with headquarters at The University of Texas at Austin and has the task of defining and carrying out the most cost-effective R&D program for tapping this source of domestic oil. It is my recommendation that the R&D program defined by the participants in that Institute should be supported because I believe it can contribute significantly to the domestic supply of liquid hydrocarbons.

I feel certain that gaseous hydrocarbons will be important as energy fuels for a long time. Gas is an attractive and efficient fuel for home heating, it is a most versatile industrial fuel, and it may be used as a substitute fuel in oil- and coal-burning electric power generating plants to reduce dramatically the carbon dioxide release per unit of energy delivered. I will say more about the use of gas later.

The domestic supply of natural gas will be enhanced by the success of R&D described earlier for both discovery and production of new oil reservoirs and enhanced recovery of oil from old reservoirs. In addition,

R&D needs to be done on the production of natural gas from tight sands, from coal deposits, and from geopressured, geothermal reservoirs.

When I speak of coal I mean all solid hydrocarbons from lignite through bituminous coal to anthracite coal, all of which can be used as energy fuels. It is well known that the United States has a very large supply of economically recoverable coal--enough to supply the energy needs of the country for several hundred years. I believe coal will continue to be a major energy source for this country for many years to come and that it will be mostly used as fuel for electric generating plants. Because of the problems of using coal, substantial R&D efforts are justified on many fronts.

First, for underground mining of coal there is the continuing, though lessened, problem of miner health and safety. R&D is needed to further improve this situation. With all of the recent developments in computers, robotics, and automation it seems appropriate to work on automating underground mining further both to protect the health and safety of miners and to lower the cost of production.

Much of the coal in this country is strip mined. Additional R&D on reclamation is justified to ensure that the land reclaimed after strip mining is as productive and valuable as possible.

In the combustion or other uses of coal it is necessary to deal with the ash and other troublesome substances contained in the coal. For example, much of the coal in this country contains significant sulfur in both organic and inorganic compounds as well as nitrogen containing compounds and trace amounts of heavy metals. In short, coal is "dirty" and its use requires cleanup to meet a variety of environmental standards. I am strongly in favor of a vigorous R&D program looking at clean coal technologies of all sorts.

Currently, our most successful and widely-used technologies clean up the coal after it is burned. We have precipitators and baghouses to collect the fly ash and scrubbers of several types to collect the sulfur dioxide and sometimes the oxides of nitrogen. These devices can be improved through properly-focused R&D. However, philosophically, it seems that cleanup after combustion is the hard way to do the job. It seems to me that clean-up before combustion should be easier. The coal is cool and there is plenty of time to process it. I recommend concerted R&D efforts to clean coal in such a way that a clean, solid hydrocarbon fuel results that can be burned with only carbon dioxide and oxides of nitrogen formed in the combustion process to worry about. Because the hydrocarbons in coal are organic it seems likely that truly adventuresome R&D in molecular biology and biotechnology applied to coal might prove fruitful.

On the question of the production of synthetic liquid and gaseous hydrocarbons from coal, we already have technologies that work but the products are significantly (roughly a factor of two) more expensive than the natural varieties. I believe continued R&D on these technologies is justified to the extent that it really addresses the basic reasons for the relatively high cost of the product.

Clearly, at some time in the future when the natural supplies of liquid and gaseous hydrocarbons become scarce and more expensive to produce, synthetic liquid and gaseous hydrocarbons will be needed for those uses in

which the fuel form is essential (for example, liquid hydrocarbons to fuel airplanes). It is likely that these synthetic fuels will come from coal because the coal resource is so large. If these synthetic fuels are to be produced by available technology, I do not believe that the transition will occur for many decades. A radically new technology that can reduce dramatically the cost of synthetic fuels could hasten the transition. It is my belief that such a new technology is likely to be biological in nature, hence I recommend the support of R&D on biotechnology for the production of synthetic fuels from coal.

In spite of the possibility of less expensive synthetic fuels from coal it is my strong belief that the most economical way of obtaining energy from coal will, for many decades to come, continue to be the direct combustion of coal to produce electricity. I believe this will continue to be true even with the technologies needed to meet environmental standards.

The extraction of hydrocarbons from oil shale and tar sands is currently technically feasible but the cost makes them uncompetitive. R&D should continue on those aspects of the technology that most affect the cost, but the fundamental nature of the process, a small amount of fuel from a large amount of material, may so constrain the economics that fuels from these sources will only be economically attractive when the natural varieties become much scarcer and much more costly to produce.

Uranium is currently used in light-water reactors to produce about 20 percent of our electric energy. This makes uranium second to coal in the fraction of electricity generated. There are about 110 reactors operating in this country; they have been performing well and their reliability is improving steadily; but their operation and maintenance costs are high and increasing. There is public concern about the safety of nuclear plants and about the handling and management of radioactive wastes.

Before I cite what I think are the R&D needs in the nuclear fission area, let me state that I believe that nuclear fission is essential to the world as a major energy source that can supply electricity in the safest, most economical, and least environmentally intrusive way of all the alternatives.

In the mining of uranium, the R&D to automate the underground mining process cited earlier in connection with coal mining, should be adapted as well to underground mining of uranium. As an alternative, because uranium-bearing compounds in uranium ore occur in such small quantities it may be useful and economic to develop solution mining techniques to avoid moving so much material.

On the topic of reactor types to produce energy, there is considerable talk these days about "inherently safe" reactors that will "guarantee" the safety of nuclear plants. I do not agree with that line of thinking. A nuclear reactor, even an "inherently safe" one, poses two fundamental dangers that need to be dealt with. First, a reactor core is typically supplied with a three-year supply of fuel. If energy is released too rapidly a serious accident can occur. Second, as the fuel is consumed there is a buildup of radioactive fission products and actinides that must be contained. I believe the currently-used, light-water reactors have proven that they provide adequate protection from both dangers. I recommend continued R&D on light water reactors to improve their durability and reliability and to reduce their operating and maintenance costs. For

example, some careful research on water chemistry and its interaction with piping and other materials can reduce corrosion and its several consequences.

Whereas I believe the currently-used, light-water reactor types with incremental improvements can provide an adequate, safe, and economical supply of nuclear-fission generated electricity for many decades, I also believe that R&D on two other reactor types is warranted. I believe that the high-temperature gas-cooled reactor (HTGR) has potential to provide a large-scale, economical supply of high-temperature process heat. R&D should continue on the HTGR for that purpose. If fossil fuels become scarce and expensive or if their consumption is restricted because of the greenhouse effect or acid rain, the HTGR could provide a useful source of process heat and steam for industry.

The second type of reactor that I believe will be needed in the long-term future is a breeder reactor. As the readily available, low-cost uranium is consumed, which will be many decades hence, a breeder reactor can consume the depleted uranium from the enrichment process and multiply the energy available from the uranium by more than an order of magnitude. I believe that we need to ensure that either the liquid-metal-cooled fast breeder reactor (LMFBR) technology or the gas-cooled fast breeder reactor (GCFR) technology is available when needed.

The radioactive wastes produced by the fission process must be dealt with properly to avoid an unwarranted threat to health and safety. I believe that techniques are available for accomplishing this objective economically. I feel that the current plan to geologically isolate spent fuel rods can succeed technically and economically; however, I think it is a mistake. It seems to me illogical for a society so intent on conserving all the resources we can, to be willing to dispose of spent nuclear fuel rods that still contain substantial energy content. I am in favor of recycling spent fuel rods both to recover the remaining fissionable material for future use in new fuel rods and to reduce the volume of high level radioactive wastes that must be dealt with. I realize that under current conditions, fuel reprocessing does not appear to be economical so I recommend retrievable storage for spent fuel rods so they can be reprocessed when it is economical to do so.

It is likely that geological isolation of radioactive wastes will be needed as an interim measure and possibly as a long-range measure for dealing with these wastes safely and economically. As a consequence, it is fitting to continue research on long-term migration and chemical reactions that can occur with radioactive wastes in suitable geological formations.

Whereas I agree that geological isolation of high-level radioactive wastes can be accomplished safely and economically, I do not think it is a fitting, long-term (I mean hundreds of years) way to continue to dispose of radioactive wastes, especially if the use of nuclear fission power worldwide expands significantly, which I think is highly likely. I believe research should be done on methods to convert radioactive wastes to non-radioactive, non-toxic substances that can be dealt with in simple ways. I understand that this can, in principle, be accomplished by first separating each radioactive constituent from the rest of the waste and then processing each constituent appropriately. Because each radioactive element is present in such a small quantity, separation by chemical or physical processes requires

much more precision than has generally been available. After separation, each radioactive element can be dealt with appropriately. Some may have commercial value while others will need to be bombarded with neutrons of appropriate energy to transmute them to non-radioactive, non-toxic elements. Success in this effort can assure that long-term, large-scale use of nuclear fission is not encumbered by a need for long-term storage of ever-increasing amounts of radioactive wastes. In my view, the potential benefit makes this an important area for long-range research support.

Nuclear fusion, the process by which light isotopes (usually of hydrogen) fuse to form heavier elements and release energy, has received much attention as a possibly attractive energy source for the future. The fundamental appeal of fusion arises from two characteristics. First, its primary fuel is deuterium, an isotope of hydrogen, that occurs as 1 part in 6600 in all the waters of the world. In terms of the energy it could produce, this deuterium represents an almost inexhaustible supply and the cost of separating it from water is negligibly small. The second characteristic is that fusion reactions do not produce radioactive reaction products although some of the reactions most likely to be of interest produce neutrons that will render materials they strike radioactive. A brief history of fusion research and assessments of its potential is in order.

The fundamental attractiveness of fusion was recognized in the 1950s and research on controlled fusion was started with the primary purpose of developing a new energy supply. Research proceeded at a relatively low level of funding until the early 1970s when it was decided that a larger research program had a chance of bringing into being practical fusion power. Over a few years the U.S. fusion program funding was increased by an order of magnitude, a timetable was set to produce a demonstration fusion power plant, and conceptual power plant designs were started based on physics performance expected and materials that were available or could reasonably be expected to be developed. A well thought out and comprehensive program was laid out in which all research and development was required to be "reactor relevant"--that is, it was required to make demonstrable contributions to the development of a fusion power plant.

During the following decade dramatic theoretical and experimental advances were made in the understanding of fusion plasma physics, fusion experiments became much more costly, and the conceptual power plant designs turned out to appear economically unattractive. Efforts were made in the program to improve the conceptual designs but they were unsuccessful in overcoming the fundamental problems with the projected use of fusion, as currently conceived and understood, as a power source. Furthermore, in spite of the money spent and the scientific advances made, controlled thermonuclear fusion has not been produced experimentally so we do not really know for sure what it will be like.

In my opinion the U.S. fusion program as currently planned, in which information is to be developed on the basis of which industry can make choices about fusion power plants, is doomed to failure, independent of the funding level. I recommend that the mission of the program be redefined as a research program directed to the production and scientific study of controlled fusion and that potential applications be considered only after controlled fusion has been produced experimentally and understood reasonably well scientifically.

In such a restructured and reoriented fusion program, attention should be given to the least expensive ways of experimentally producing fusion for scientific study including high-field magnetic confinement, muon-catalyzed fusion, and the so-called "cold fusion" recently reported from Utah. I feel confident that controlled fusion can be produced successfully, but I predict that the early commercial applications of fusion will not be for energy supply.

Solar energy is the other source that I feel has a chance of providing a significant fraction of our energy supply at some time in the future. Solar energy manifests itself in several ways and can be collected and converted to useful forms using a variety of technologies.

First, the collection of direct solar radiation and conversion to useful forms can be accomplished in three fundamentally different ways. Fixed, flat-plate collectors of simple design and inexpensive construction can produce so-called "low quality" (meaning relatively low temperature and low pressure) heat that is nonetheless useful for heating living space and heating water for domestic, commercial, and industrial use. There is little opportunity for further technological improvement so the question of whether or not this form of solar energy is used is a matter of relative economics. When the cost of heating water and space by other available means (gas, oil, or electricity) is too high, solar heating is attractive which is already the case in some areas. Little additional R&D needs to be done in this area.

The second method of collecting and using solar radiation is to produce "high quality" (relatively high temperature and high pressure) heat that is suitable for driving turbomachinery efficiently. The solar radiation must be concentrated as with a magnifying glass and this requires more complicated collectors that track and focus the sunlight. Demonstration projects have been built to test the technology and it has worked well but proven more expensive than alternatives by a sizable margin. It appears that the attractiveness of this concept depends on the cost of alternate fuels and technologies.

The third method of collecting and using solar radiation directly is through solid-state electronic materials that produce electricity directly (photovoltaic cells) or that produce hydrogen and possibly some electricity. It appears to me that there is opportunity in this area for advances from undertaking further R&D. Progress has been made in programs supported by DOE and in programs supported by EPRI. Photovoltaic generation of electricity is already economically competitive in some applications such as powering remote microwave repeaters. As the costs of photovoltaic systems come down and/or as the costs of alternative sources increase, photovoltaic conversion can find wider use. It is my opinion, though, that photovoltaic generation of electricity will not become a major factor in the total electricity supply of the U.S. for many decades, if ever. Nonetheless, I feel that R&D on photovoltaic generation should continue at a reasonable level.

The form of solar that has for some time and will continue into the indefinite future to be a major factor in the electricity supply of the country, with special impacts regionally, is hydroelectric power. Unfortunately, practically all of the large-scale, economically attractive hydro sites in this country have been developed and the remaining small-

scale sites can provide little energy. As a consequence, little R&D on hydropower is justified.

Other manifestations of solar energy such as wind and ocean thermal gradients are essentially small scale and local in nature. Whereas wind generation may be justified in some areas as a fuel-saver it cannot, in my view, have a major impact on the nation's energy supply. It deserves little R&D support.

Tides and waves in the ocean can be characterized at best as intermittent, very low-head, hydro. As such they are capable of generating little energy on the scale of the national usage and are not worthy of energy R&D support, in my view.

Geothermal energy, the energy from the hot core of the earth, manifests itself in certain localities by relatively shallow deposits of steam or hot water or relatively shallow occurrence of hot dry rocks. This energy source can be tapped and is sometimes economically attractive as in the Geysers field in California. Although geothermal energy will have only a local impact where it is readily available, it is deserving of R&D support to make the conversion process more reliable and economical and to mitigate environmental impacts.

A final energy source that is used currently and whose use should expand is industrial and municipal wastes. Many of these wastes have significant energy content and their disposal is a problem. Their use as energy fuels, usually through combustion, can reduce their volume substantially. I believe R&D should be supported on ways of extracting useful energy, limiting environmental impacts, and safely disposing of the wastes that result.

In summary, I am of the opinion that the U.S. energy supply for the next hundred years or so will come mostly from oil, gas, coal, and uranium, with small contributions from hydro and other solar based sources, from industrial and municipal wastes, and from geothermal. I believe that energy supply R&D funding should be dedicated both to improving the economics of our primary sources and lessening their environmental impacts and to the development of long-term options like breeder reactors, fusion, and solar photovoltaics.

One final aspect of energy supply that I want to address is the generation, transmission, and distribution of electric energy. The fraction of our energy supplied as electricity has grown steadily over the years and it appears that this growth will continue both because electricity is so convenient and versatile as an industrial, commercial, and residential energy source, and because two of our major energy sources, coal and uranium, are most conveniently and economically made available in the form of electric energy. Research and development are needed to make our electric generating plants operate more economically and more reliably and with longer service lives. Research is needed to resolve whether or not electromagnetic fields from transmission and distribution lines pose a threat to humans, animals, or plants, and research is needed to explore how best to deliver electricity over the long term. Power semiconductor electronics and high-temperature superconductivity can both have major impacts on how we generate and deliver electricity and our R&D should address their uses.

The Electric Power Research Institute (EPRI) provides most of the funding in this country for R&D on electric energy generation, delivery, and use. I am of the opinion that the current level of funding is inadequate for the need and should be increased, possibly by augmentation with Federal funds.

Another aspect of energy R&D that needs to be addressed here is what is commonly called end-use. I will address it in three parts.

First, about 35 percent of the energy currently consumed in this country is consumed by the industrial sector. Our industry has in the past enhanced and will continue in the future to enhance its competitiveness both by improving the way it currently uses energy and by adopting novel ways of using energy to lower the cost of production. Research and development can and does contribute in both of these areas, and especially in the latter where novel forms of energy like those provided by microwaves, lasers, and electron beams can be put to work to improve industrial processes. The Gas Research Institute (GRI) has an active R&D program directed to better industrial use of gas and EPRI has an expanding program to support industrial use of electricity. These R&D efforts may need to be augmented to help U.S. industry be more competitive globally.

The second major part of the end-use picture is residential and commercial use of energy. Major uses of energy in this sector include heating, cooling, lighting, refrigeration, and cooking. Research and development in this area is warranted to provide the desired services at less cost and both GRI and EPRI have major R&D programs in residential and commercial end-use technologies.

The final major consuming sector is transportation. This sector is supplied almost totally by liquid hydrocarbons with a very small amount of gaseous fuel use and even less electricity. Companies supplying transportation technologies have made great strides over the past 15 years in reducing fuel consumption and, presumably therefore, cost per mile travelled. Such improvements will likely continue to accrue but not as rapidly as in the past. Automobile companies have also put considerable money and effort into reducing exhaust emissions. Nevertheless, the air quality in large urban areas is often poorer than desired and it is felt that automobiles and trucks are major contributors. If the conclusion is reached that the use of liquid-hydrocarbon-powered autos and trucks must be curtailed drastically, there will be a need for alternative urban transportation. It is likely that people will still want individual transportation and there will be a need for delivery and service vehicles. Alternatives that should be considered are electric-powered vehicles using rechargeable storage batteries and hydrogen-fueled vehicles using either fuel cells and electric drives or internal combustion engines with mechanical drives.

The greatest need for a vehicle driven by a rechargeable storage battery is a better storage battery. R&D on storage batteries is being funded currently by EPRI, the Electric Vehicle Council, and the battery companies. An increased level of funding may be in order.

A hydrogen-powered vehicle needs both a source of hydrogen and a suitable fuel cell or internal combustion engine. R&D support is warranted in all three areas: the production of hydrogen, the development of a better

fuel cell, and the development of a better internal combustion engine to operate on hydrogen.

A very important topic in energy production and use is always conservation. It is my impression that conservation for conservation's sake, or in other words, curtailment, is not something the majority of the American people embrace. Using energy more efficiently and cost effectively to do the jobs we want and need done does make sense for all of us. I believe that energy efficiency and cost effectiveness should always be objectives of our energy R&D activities whether in production, delivery, or end-use.

A final topic I want to cover is the role of university-based R&D in "Creating the New Wealth: R&D Funding in the 1990s." In my view, university-based research plays two roles. First, and most important, it produces well-educated graduates who will make their contributions to a better world. The more relevant the research that they and their faculty are involved in, the better prepared they will be to contribute after graduation. The second role of university-based research is to produce new and innovative ideas. Graduate students are generally very bright, highly imaginative, and unencumbered by current practice and conventional wisdom. They are usually full of new ideas, some of which are good and some of which are not. The academic environment is especially conducive to generation and examination of new ideas and through these activities major benefits can accrue.

It is my impression that the expected demand throughout the 1990s for scientists and engineers with advanced degrees will not be filled by the number currently expected to graduate. As a consequence, I believe there is a need for substantially increased federal funding to support the education of graduate students in science and engineering.

Because of the nature of an academic environment, and particularly the relatively short residence time of students and the classroom teaching duties of the faculty, not all R&D projects are suitable for a university setting. In particular, applied research projects with tight schedules and short deadlines and large development projects are not appropriate for most universities.

This concludes the formal testimony I wanted to give. I appreciate the opportunity to testify and I hope my thoughts will be useful to the Committee in its deliberations.

Thank you.

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Biographical Sketch of

Praveen Chaudhari

Praveen Chaudhari is Vice President for Science at the IBM Thomas J. Watson Research Center in Yorktown Heights and member of the Corporate Technical Committee.

Praveen Chaudhari graduated from the Indian Institute of Technology, Kharagpur, India and received his doctoral degree from M.I.T. in 1966. He joined IBM the same year and over the years carried out his personal research, held various management responsibilities in science, and science related to technologies such as the optical storage, magnetic bubbles, and the Josephson program. He was appointed Director in 1981, Vice President in 1982 and member Corporate Technical Committee in 1989.

Chaudhari has worked on the structure and properties of amorphous solids, mechanical properties of thin films, defects in solids, quantum transport in disordered systems, superconductivity, and on the magnetic monopole and neutrino mass experiments. He has published over ninety technical papers, edited two books, and holds over a dozen patents. He is a member of the National Academy of Engineering, a fellow of the American Physical Society and member of the American Institute of mining, Metallurgical and Petroleum Engineers and of the American Association for the Advancement of Sciences.

He is a member of the Visiting Committee for the Physical Sciences, University of Chicago; for the Materials Science and Engineering Department, Massachusetts Institute of Technology; and for the School of Engineering, U. of Illinois. He is a member of the Science Advisory Board of the Hoechest- Celanese Corporation. He serves on a number of professional committees including the national study on Materials Science and Engineering sponsored by the National Research Council. He is co-chairman of this study. He is a member of the solid state sciences committee of the National Academy of Sciences and member-at-large of the Governing Board of the American Institute of Physics.

He has won a number of IBM awards and is also the first recipient of the Leadership Award (1986) of the Metallurgical Society of AIME for his contributions to advancing the science and technology of electronic materials. He is also recipient of the George E. Pake Award of the American Physical Society (1987) for his personal contributions to science and management of science.

He is secretary of President Reagan's Advisory Council on Superconductivity. He is a member of the National Commission on Superconductivity appointed by the President. Chaudhari is a member-at-large appointee of Governor Cuomo to the New York State Institute on Superconductivity.

SCIENTIFIC CONTRIBUTIONS

Mechanical Properties and Defects in Crystalline Solids

Chaudhari's interest in defects dates from his graduate school days when he published his first paper showing how a Frank-Read source can operate to multiply dislocations in an ordered alloy. Also, in a classic and simple experiment, Chaudhari and Matthews provided the first direct experimental demonstration of coincidence grain boundaries by measuring the tilt angles occurring in MgO smoke particles.

In a series of papers Chaudhari has explained why the observed mechanical properties of single crystal and polycrystalline thin films are different from those of the corresponding bulk. He has provided an explanation of the intrinsic stress observed in thin films and was the first to apply a stress induced diffusion mechanism to explain the growth of protrusions, called hillocks, in polycrystalline films.

Amorphous Solids

In investigations of the structure of amorphous solids he and his collaborators have shown that the celebrated electron microscopy results obtained by the Cavendish group at Cambridge University, purporting to show microcrystals, were in fact an artifact of the imaging process. They also showed by a series of simulations and experiments that similar images could be obtained from non-crystalline models of amorphous solids. Chaudhari and his collaborators have also demonstrated that there exists a well-defined transformation for amorphous solids which allows a transition from a dense random packed model to a network model and vice versa. This transformation was the first demonstration of the topological similarity between these two apparently different classes of amorphous solids - one is metallic and the other a covalent bonded network such as that found in amorphous silicon. More recently, Chaudhari and his collaborators have worked on defining and establishing the role of defects such as vacancies and dislocations in amorphous solids. They have demonstrated by computer simulation techniques that the notion of vacancies in amorphous solids is a function of the bonding present between atoms. They have shown that edge and screw dislocation can be defined in amorphous solids. These defects have elastic properties which are similar to those of crystalline solids. However, their topological properties are different.

Chaudhari and his collaborators were the first to recognize (and patent) that the strong uniaxial magnetic anisotropy in amorphous systems, particularly the rare-earth transition metal alloys, could make these materials useful for storage applications. The initial paper, now a Citation Classic, has triggered worldwide interest in these materials and they are currently being explored for magneto-optic applications in disc storage.

Quantum Transport

Chaudhari has also worked on the experimental verification of the prediction that in one dimensional metallic wires, at sufficiently low temperatures, all electronic states are quantum localized and the metal behaves as an electrical insulator. Chaudhari and his collaborators were one of the two groups that independently provided the first direct experimental evidence that such effects are indeed present.

Superconductivity

Chaudhari and his collaborators were the first to show that the high temperature superconductors could carry large critical currents at high temperatures. They were also the first to provide direct experimental evidence that grain boundaries were responsible for the low critical current in polycrystalline samples.

Magnetic monopoles and neutrino mass experiments

Recently Chaudhari recognized that solid state science considerations are crucial to both the search for magnetic monopoles and to the determination of the neutrino mass. Therefore, he initiated research projects on these topics and is an active participant in both. The use of low noise SQUID detectors and of specially designed large superconducting metal loops are essential in the search for the magnetic monopoles. Similarly, the mass of the neutrino is measured by using a tritiated source whose structure and composition will determine the accuracy with which the mass can be determined. These two experiments are considered to be among the most important in contemporary physics.

Education and Employment

Education:

B.S. (Honors) Indian Institute of Technology 1961

M.S. (Physical Metallurgy) Massachusetts Institute of Technology 1963

Sc.D (Physical Metallurgy) Massachusetts Institute of Technology 1966

Positions Held:

Danish Atomic Energy Commission, 1964

Research Associate at MIT, 1966

Visiting faculty, Harvard University, Div., of Engineering and Applied Physics, 1974.

Joined IBM T.J. Watson Research Center as Research Staff Member in 1966

Promoted to manager in Physical Sciences Department in 1970. Various management positions in the seventies, including that of coordinating the magnetic bubble, optical recording, and Josephson technology programs in the physical sciences.

Acting Director of Physical Sciences Department in 1980

Director of Physical Sciences Department in 1981

Vice-President, Science, in 1982

PROFESSIONAL ACTIVITIES

Affiliations:

Fellow-American Physical Society

Member-American Institute of Mining, Metallurgy and Petroleum Engineers

Member-American Association for the Advancement of Science

Member-National Academy of Engineering

Boards, Committee and Panel Membership (1984 - 1988):

1. The George Pake Award Committee of the American Physical Society.

2. The Mehl Award Committee of the AIME.

3. The Distinguished Lecture Award Committee of the AIME.

4. The Electronics Materials Committee of the AIME.

5. The Corporate Associates of the American Institute of Physics.

6. Served on ad hoc committees at various universities including Berkeley, University of Pennsylvania, and the Ohio State University.

7. Member, Visiting Committee to the Dept. of Materials Science and Engineering, MIT.

8. Member, Visiting Committee to the Division of Physical Sciences, University of of Chicago.

9. Member, Visiting Committee to the School of Engineering, University of Illinois.

10. Member, Advisory Committee to the National Sciences Association, University of Pennsylvania

11. Member of the Science Policy Board to Stanford Synchrotron Radiation Laboratory, Stanford, California

12. Member of the Brookhaven National Laboratory Physics, ADD, AGS, NSLS, and Instrumentation Visiting Committee.

13. Chairman of International Union of Pure and Applied Physics Commission on the Structure and Dynamics of Condensed Matter.

14. Committee on "Physics for the Next Decade" sponsored by the National Research Council of the National Academy of Science.

15. Committee on "Opportunities in Physics" sponsored by the National Research Council of the National Academy of Science.

16. Member, Review Committee on "Microgravity Science" - sponsored by the National Research Council of the National Academy of Science.

17. Member Advisory Panel for "National Symposium on Advances in Materials" - sponsored by the National Academy of Sciences and National Academy of Sciences and National Academy of Engineering.

18. Member, Solid State Sciences Committee of the National Academy of Sciences.

19. Member, Steering Committee on "Management and Acquisition of Instrumentation at Universities" - sponsored by the Association of American Universities and Land Grant Colleges.

20. Co-chairman of "National Materials Science and Engineering Study" - sponsored by the National Academy of Science and the National Academy of Engineering.

21. Member of the Science Advisory Board to the Hoechest-Celanese Corporation.

22. Member-at-large of the Governing Board of the American Institute of Physics.

23. Member-at-large of the New York State Institute of Superconductivity.

24. Secretary to the President's Advisory Council on Superconductivity.

AWARDS

1. Several IBM awards for his scientific contributions to the field of superlattices, structure of grain boundaries, structure of amorphous solids, and amorphous magnetic materials.

2. Leadership Award of the Metallurgical Society of AIME for his scientific and technological contributions to the advancement of electronic materials.

3. George E. Pake Prize of the American Physical Society in 1987 for his outstanding management in enhancing the role of basic research in the materials and processing science in the scientific and technological community at-large, and for his scientific insight and creativity in understanding the structure and properties of amorphous thin films and fine lines.

STATEMENT OF DR. PRAVINE CHAUDHARI, CO-CHAIR, ACADEMY OF SCIENCES STUDY "MATERIALS SCIENCE AND ENGINEERING FOR THE 1990s," AND VICE PRESIDENT, SCIENCE, THOMAS J. WATSON RESEARCH CENTER, IBM CORPORATION, YORKTOWN HEIGHTS, NEW YORK.

Dr. CHAUDHARI. Mr. Chairman, members of the House Science, Space, and Technology Committee, first of all I want to thank you for inviting me to express my opinions on the role of materials in the competitiveness of the United States.

Although the opinions I will express are my own, they have been shaped both by my experiences at IBM and also by experience and responsibility as Co-Chairman of a study, "Materials Science and Engineering for the 1990s."

This study was carried out by a committee of the National Research Council under the guidance of the National Academy of Sciences and the National Academy of Engineering. The study has been completed and is in the process of being published. It will come out sometime this July, and I would be happy to come back and describe in more detail, either individually to you or as a committee, what we have learned from that. The results are important in terms of understanding the role and materials in competitiveness.

In my testimony today, I want to touch on three topics. The first is the role of materials in certain industries. We feel that it is indispensable and therefore essential for these industries to be in advanced materials if they are going to compete in the world as we know it today.

The second point I will touch on is that materials research can be divided into a few broad classes and that the response that we have as a government or as a body to that will depend on which category of class of materials research we are talking about. So it is essentially those three topics that I will touch on today.

It has frequently been said that materials are very important to industry. In order to examine that, what we decided as a study to do was to go and ask the industry folks, people who have senior management responsibility, but who are also technically inclined, to come and tell us how materials affect their industry.

What we asked them was: suppose you had complete access to the development of a material, and suppose you could produce any material you wanted to. How would this impact your industry in terms of competitiveness? Where would it take your industry?

We learned a great deal from that, that there were significant materials developments required in terms of competition. I have summarized the eight industries that we looked at in the document that I have given you. I will not go into the technical details of what was expressed there, but try to summarize the feelings that emerged from that.

The second thing we learned by going to these industries was that they felt by and large that the role of the government was essential in helping them do materials research. This was somewhat surprising to most of us on that committee.

Now, in order to make sure that we had really understood the role of materials in competitiveness, we also went and asked our

colleagues abroad with whom we trade, particularly countries such as Japan, West Germany, France, the United Kingdom, South Korea and the Soviet Union, as to what role they see for materials in their respective countries.

What we learned was that, along with biotechnology and along with computer and information technology, materials science and engineering was regarded as the fundamentals that they would wish to emphasize in their countries. We also found that these countries take the role of developing materials in a very specific way. They play a very active role in making sure that specific areas of materials are developed for their technologies. In other words, the emphasis on materials into the policy, and which emphasis they are going to pay on in which industry.

As far as looking at how materials can be developed, it is probably the best way to approach that, rather than describe to you in great technical details the kinds of materials, to just take a few examples from a few selected industries.

Let me take the first one from the electronics industry. As you heard earlier in the day, we are currently producing a 1-megabit chip, and the 4- and the 16-megabit chip is on the horizon. It is reasonable to ask if you could produce a gigabit chip that is a thousand times more dense than what it is today, you would have a decisive advantage in the marketplace. What stops us from doing that?

The answer is basically there is no fundamental law of physics that says we cannot do it. It is a series of advances over a wide variety of materials, the control and the process that limits us. It is this iterative cyclic process that Ralph Gomory referred to, that basically slows us in that development. So here, materials are essential, but it is a development of materials on a very broad front that is needed in a continuous fashion.

This is in sharp contrast, if you like, to high- temperature superconductivity, which is another material where you basically have a new discovery. Here you do not know the properties of the material. You do not know for sure that you can use this material for practical applications. If you knew that, then it is basically an iterative process.

So here the government's role is quite different. Rather than let industry, which has the base of knowledge in the case of silicon, in the case of high-temperature conductivity, the base of knowledge would reside at universities because they have the expertise in science and basically the fundamental base.

So there, the role the government plays has to be quite different. The emphasis has to be on research and the emphasis has to be on determining what are the properties of these materials if they are ever going to be useful. And the time scale we then talk of is relatively unpredictable.

In the iterative, cyclical way, we know we have to move as fast as we can, and we generally have a time frame in our own industry, whereas in the case of superconductivity it is hard to project. So we have to plan in a long-term commitment something which we have to persevere in. These are the two extremes.

On the other hand, there are materials like gallium arsenide which are in between, and there our approach has to be still differ-

ent. Let me talk a little bit more about gallium arsenide because it reflects in a particular way. It has been known for two decades that gallium arsenide as an electronic material is superior to silicon in many ways. It is not only a material that you can use for lasers, but it is also material that gives you a speed power advantage of a silicon. What does that mean? It just means that if you were trying to operate your transistor at the same speed, you could do so at a lower power; or if your power was fixed, you could operate your transistor faster.

These properties have been known for two decades. But what was missing in this case is that knowledge or the base of knowledge that allowed you take advantage of these materials. So here you had a material that was competing with something that was already in place, but what you needed to put in place was a plan that would allow you to develop this material in a time frame where it's competing with silicon. In other words, you had to put a plan in place so gallium arsenide could be developed over a period of time where it would come up to a sufficient point where industry could take advantage of it.

So the role of government here is quite different. There are no fundamental laws again, but there is a gap in knowledge. And that knowledge needed to be generated before industry could take advantage of it. And there you see a mixture of industry and universities playing about an equal footing.

I have taken these three examples to illustrate that you can take materials, divide them broadly into these three different classes and show that the role that the government has depends on which material and where it stands relative to other materials or relative to your product.

One of the things we found in our study which underlay almost all of these classes of materials was a need to emphasize synthesis and processing. Let me talk a little bit about what we mean by synthesis and processing because, on the one hand, it impacts science or scientific discoveries; on the other hand, it impacts the manufacturing flow. So it is a very broad spectrum of activities we are talking about.

What we found in our study was that this is an area of science and engineering that the United States is particularly weak in. It is an area of science and engineering that almost every country puts considerable emphasis on because it is the science and engineering that allows you to develop new materials on the one hand, and yet develop them to the point where you can manufacture or understand how to manufacture them.

On the one hand, you had scientists that believe they are now approaching a point where they can take clusters of atoms or take atom by atom and literally build a solid with the desirable properties. And, on the other hand, you have engineers who feel that they can develop process now where they use computer control and dynamic sensing to what they call intelligently shape materials. That is the processing end, and the first is the synthesis end.

If there is one message that I would like to leave with you in the sense of emphasizing the research basis, it is that synthesis and processing is one we need to pay very much more attention to than

we have in the past, both at the university level and at the industry level.

So, Mr. Chairman, let me summarize. I've tried to make essentially three points. First of all, that materials research is very important to industry, to a wide variety of industry; secondly, that synthesis in processing as a general area of materials research is very important, both from the point of view of manufacturing at the one extreme and the point of view of making novel materials which lead to major discoveries at the other extreme; and third, that the role of government has to be active. However, there is no one single approach, and that depending on the particular circumstances, one has to modify one's approach for that.

Thank you very much.

[The prepared statement of Dr. Pravine Chaudhari follows.]

Mr. Chairman and members of the house Science, Space, and Technology Committee, I want to thank you for the opportunity to provide my views on how materials research contributes to the economic well being of our nation. These views are informed both by my responsibilities within IBM and by my role as co-chairman of a recently completed study entitled ***Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials***. The study was prepared by the Committee on Materials Science and Engineering (COMMSE) of the National Research Council.

My remarks will touch upon three topics. (1) Materials are indispensable for the products of many industries. To these industries advances in materials are essential if they are to compete in the world as we know it today. (2) Materials research, as it relates to industry, can be divided into a few broad categories. This categorization depends on how well we understand the material and its relationship to ongoing or potential applications. Underlying all of these categories is the need for a strong base in synthesis and processing of materials. (3) The government's role in materials research should be active. The many roles it can play are discussed briefly.

In the course of the work of COMMSE, we evaluated the impact of materials science and engineering by surveying its role in industries considered important for commerce and defense and then looking briefly at needs of the public sector, particularly of governmental units whose missions involve defense, energy, transportation and space. Eight industries were chosen to be surveyed that represent different aspects of the use of materials. These were aerospace, automotive, biomaterials, chemical, electronics, energy, metals,

and telecommunications industries. The eight industries collectively employed 7 million people and had sales of $1.4 trillion in 1987. In addition, they were critical to many millions of jobs and to large sales in ancillary manufacturing industries.

The surveys of the eight industries were carried out by people with senior management and technical responsibilities in their respective industries. Hence the results of the surveys are particularly important in two respects. First, they represent a sample of industry views regarding materials science and engineering and its impact. Second, they represent technical management views on how materials science and engineering should be structured by policy makers to fully exploit the opportunities that lie ahead. The results of the surveys show that materials science and engineering is viewed as vital by all eight industries. The idea also emerged, strange as it may sound coming from U.S. industry, that it is important for government to play a leadership role in helping to identify research areas of national importance, so that materials science and engineering can be more fully exploited.

As an independent measure of the importance of materials science and engineering in competitiveness, we also gathered information through a questionnaire sent to materials science and engineering leaders in competitor countries and obtained additional data from the science attaches of foreign embassies, from case studies on representative industrial sectors, and from the open literature. We compared the activities of other countries with practices in the United States. The countries surveyed included several traditional U.S. trading partners (Canada, West Germany, France, and the United

Kingdom), a major economic competitor and strategic ally (Japan), a newly industrialized country (South Korea), and the principal U.S. strategic competitor (the Soviet Union).

The most striking observation supported by the gathered information is that all the major nations are strongly committed to industrial growth stimulated by coordinated R&D in which materials science and engineering is a featured element. In fact, of all the industrial areas in which growth is anticipated for the next decade, materials science and engineering, biotechnology, and computer and information technology were targeted by all of the nations surveyed.

Another significant observation is that cooperative mechanisms, fostered by government involvement, are being used increasingly by competitor nations to enhance industrial competitiveness.

As part of my testimony, Mr. Chairman, I am enclosing details of our findings of the eight U.S. industries as well as our survey of materials science and engineering in the selected countries. The survey of eight industries provides considerable detail of the type of materials research needed to support their efforts. Due to limitations of time I shall not enumerate either the research needs of the eight industries or the practices of the many governments promoting materials research.

I do wish, however, to use three examples from three different industries to indicate the essential and diverse role of materials, the way we may categorize materials development, and the role of the government.

My first example comes from the electronics industry. As you know, this is one of the most dynamic and competitive industries worldwide. As you also know, one of the key driving factors in performance and cost effectiveness is the level of integration. For example, a one megabit memory chip is commercially available today and four or sixteen megabit chips are on the horizon. If a company could leap-frog from a a megabit chip to a one gigabit chip, a thousand times more memory, surely they would have a decisive advantage in the market place.

There are no known laws of physics that stops us from producing a gigabit chip. It is only our ability to control materials and their processing that determines the rate of progress. The reason we go from one to four to sixteen megabits is the continual, derivative advances that are simultaneously required on all aspects of processing a highly integrated chip. What determines success in this game then is the rapidity with which incremental changes can be made.

My second example comes from the communication and computer industries. It is concerned both with the speed with which we process information and the speed with which we communicate within and between computers. The Gallium Arsenide family of compounds are know to have a speed/power advantage over silicon. They are also used to make solid state lasers. The properties of these materials have been known for some time. What slowed the use of these materials was not some fundamental process, but rather insufficient knowledge about how multicomponent materials can be processed effectively and once processed, how do they compete with existing technol-

ogy? The development of gallium arsenide therefore required a learning curve. Such a learning curve takes time and frequently a technology will not survive in a competitive environment without conscious recognition of its ultimate value and patience to struggle with it.

My third and final example comes from the aerospace industry. The key technical issues here are all connected with the properties of materials such as strength to weight ratio, fatigue life, fracture life, survivability, etc. For example, replacement of conventional aluminum air frames with aluminum/silicon carbide or magnesium/graphite composites would yield a seven-fold increase in payload capability. Here again, the gating factor is incremental knowledge that enables us to produce these materials in a viable way rather than a fundamental barrier.

In all three of the examples it is not the discovery of a new material or phenomena that gates progress, but rather it is evolutionary understanding and control of bringing diverse properties and materials together in a cost effective way to build a product. This is not to say that new discoveries such as high temperature superconductors are not needed, but rather once the discovery is made, their exploitation for practical purposes requires a systematic approach having both a knowledge of applications and a broad research base.

A common theme in the fabrication of a gigabit chip, a GaAs microprocessor, a magnesium/graphite composite, or a wire made of high temperature superconductors is synthesis and processing of materials. In fact, one of the two common themes that emerged from our survey of industries was the

need to enhance the strength of the U.S. research base in this area. Interestingly this also emerged from our study as an area of great intellectual activity. On the one extreme, our scientists visualize that in the not too distant future we shall be able to take atoms and synthesize atom by atom a desirable structure and in the other extreme, our engineers anticipate the processing of materials to produce shapes with desirable properties to be carried out with the optimal use of sensors and computer control - so called intelligent processing.

Let me return now to the different examples to elucidate the different roles of various institutions in developing materials for applications. In the case of the gigabit chip there is a very well established technical base residing in industry. The nature of supporting science and engineering base required to build a gigabit chip is well understood. What is needed is a marshalling of these resources in a most efficient way to achieve the end product as quickly as possible. Under these conditions, industry has to take the lead and research institutions whether at universities, industrial or government laboratories, provide the base knowledge.

The government's role here is one of facilitating the derivative process by providing a broad scientific and engineering base in materials research which industry can tap as needed.

In contrast to the gigabit chip made of silicon, the situation in GaAs is quite different. Here we understand the potential of the material and recognize that a base of knowledge needs to be generated before it can be exploited fully.

My observations are that in this type of situation the government's role needs to be more active and more directed. It needs to nurture and sustain a critical size effort over a period of time until we fully realize what the value of the new materials is relative to materials that are currently in use.

The situation in the new high temperature superconductors is still different and suggests a third category. Although one has a list of applications it is not known if the materials can be fabricated with the appropriate properties. The issue here is not one of improving with time, but rather one of ever improving due to some fundamental reason. The time scale for materials development is then unpredictable. Here research based at universities but with joint and active participation by industry and government laboratories is preferable. This, amongst other reasons, was why President Reagan's "wise men" chaired by Ralph Gomory recommended the formation of consortium involving university, industry, and government laboratories.

The examples I have chosen to illustrate the three different aspects of materials development and the role of the government are not unique. One can find and break into these three categories of materials based on their functional properties whether they be structural, electronic, magnetic, photonic or biomaterials or alternatively used within an industry which is dependent on advanced materials.

Mr. Chairman, let me conclude then with a summary of what I have tried to convey. Materials research is inextricably linked to competitiveness in the

market place in a variety of basic industries. This is recognized not only by us but also by our trading partners.

The United States is relatively weak in the area of synthesis and processing of materials. This area needs to be strengthened for it forms the basis of producing new materials and to producing conventional materials in new ways.

Materials development for the market place falls into a few broad categories. Government, university, and industry involvement is required in all categories. However, the precise role the three institutions play depends on the category.

The CHAIRMAN. Excellent.

The gentleman from New York.

Mr. BOEHLERT. I thank both of you for excellent testimony. But, Dr. Woodson, on page 10 of your testimony you talk about not meeting the demand for scientists and engineers in the '90s. We will not have the graduate students that we need. But, even more frightening to me, is the fact that we are not going to have the teachers at the elementary and secondary level to stimulate these people to that career choice.

So I think we have to go back even further. I would hope that I would have support from you, in line with endeavors that this committee is advancing, to do more in terms of scholarships and programs to encourage young people to go into public education, young people who major in science and math. I know we need them to be graduate engineers, and I know IBM, Dr. Chadhari has probably got a list a mile long of people he would like to recruit. But we are never going to get to that stage if we do not get the right people into public education to stimulate the generations of the future.

Would you comment on that in general, please?

Dr. WOODSON. Yes, I will. I almost included material about that in my testimony, but I had thought the interest was in energy-related R&D. But it may be interesting to you that we have an advisory council to our College of Engineering that is composed of about 90 senior executives from industry, and they are worrying about that right now. We have recently compiled some information on what is happening nationally and what we need to do to make our contribution.

Just a couple of numbers related to the demand for graduate engineers and—primarily engineers—but we need engineers and scientists both. I believe in the year 2000 we will need roughly 10,000 PhDs in engineering. And the best we have ever done at turning out PhDs compared to the college-age population would produce about 3,000. So we're going to be way, way short. And I think that between now and then, we are really going to have to get busy to interest more people who are prepared to study science and engineering, to do so. Not a large fraction of them do now.

Mr. BOEHLERT. Are you saying those are annual figures? Ten thousand?

Dr. WOODSON. Yes; right. Ten thousand per year.

Now, I agree with you that one of our major problems, the demographics, show that the college-age population is dropping rather dramatically and I guess the college-age population, 18 to 24, peaked out at about 30 million, 31 million in 1980, and it will bottom out at 20 million in the year 2000.

It turns out that in order to get a large enough fraction of that population ready to even study science and engineering if they wanted to, we need to start right at the first grade, and I think we need to interest people in science and engineering. I think one of our major problems is to look to the kinds of teachers we put in the schools, what their qualifications are, what their attitudes are. And I think we need to start at the very earliest level, because when a student gets to high school, if they have not properly prepared in

science and mathematics, it is all over. They simply will not be able to go into science and engineering, even if they wanted to.

So I agree with you that all of the figures I see—and I believe there are reports from the National Academy of Engineering, from the National Science Foundation—Dr. Atkinson who is President of the University of California, San Diego, used to be Director of NSF, recently gave a speech—all of those reports contain some numbers that are just downright scary about the future of this country and its need for graduate scientists and engineers.

Mr. BOEHLERT. Thank you very much. No further questions, Mr. Chairman.

The CHAIRMAN. The gentleman from Colorado.

Mr. SKAGGS. Thank you, Mr. Chairman.

Dr. Woodson, one area that you seemed to give relatively passing treatment to was photovoltaics. I am taken with the potential that exists there not only for our domestic use, but probably in terms of our trade with much of the rest of the world and the products that we can generate out of that technology if we stay ahead of the curve.

I guess my question really is both to you and Dr. Chaudhari, in that the materials side of what I understand needs to be done in photovoltaics is the critical component. One, are we giving the kind of support that we ought to through SERI or other arrangements, to our research and the materials work that needs to be done to support photovoltaics?

And, Dr. Woodson, how do you assess the potential that that technology has in terms of the subject of this hearing, new wealth, and particularly our competitive and trade position in the world?

Dr. WOODSON. Well, I hope I paid a little more attention to photovoltaics in my full testimony than I did in my summary testimony, but it is very clear that photovoltaics already have a market niche, they are already a commercial reality in areas where they are competitive. And there are areas where they are clearly competitive.

Now, in order for them to have a larger market niche, their cost has to come down. I think this results probably largely from developing better materials for photovoltaics, and that as time goes by we will have improvements. And I would comment that the Solar Energy Research Institute and the Electric Power Research Institute both have sizable programs on photovoltaics that are having some success, and I think that will continue. The photovoltaics market niche will increase but I do not think, given what I see, it will ever be a very large fraction of the overall energy supply of the country unless the cost of alternatives goes up rather dramatically.

I think at the moment, photovoltaics are simply economically not competitive for the bulk electric power generation.

Mr. SKAGGS. But in terms of our keeping our competitive position in a world market where the niche is somewhat larger than domestically, what do we need to be doing Dr. Chaudhari, in terms of your paradigms of government activism into making sure we get the materials work done that is essential there?

Dr. CHAUDHARI. Let me first give you my bias. I am a firm believer that investment in materials research eventually pays off. Having said that, I would say it certainly is a positive step as far as

I am concerned that one can increase the funding in that area. However, given a fixed sum, we sort of have to decide where we want to put more money or less money. There is a certain amount of tradeoff to be done.

In that context, if I look at photovoltaic research and materials, I would say we cover it quite adequately there. And perhaps what we need to do there is much more investment in new materials; that is, look for different materials which may have higher efficiency or a different way of processing, say amorphous silicon, so we can make it even more inexpensive or reliable.

In terms of this categorization I have done, I would say that is in the area which is closer to industry than it is to university type of research. It is somewhere at that end. For example, if amorphous silicon could be developed so you could make it out of large areas and you could make it stable so that it could be left exposed to sunlight for long periods of time without degradation, that that would be a very desirable thing.

But that is much more in the area of industry rather than university research, because we know at the university level it works.

Mr. SKAGGS. Just to test my own understanding of the potential here, and this may be relatively small potatoes compared to high definition TV, but my impression is that we really have been in a leadership position in terms of pushing the technology ahead in the work in this country and are again looking at a situation where if we do not give it some extra attention, we will be eclipsed by foreign competitors in being able to meet a world market demand for this technology.

I am wondering is that a correct assessment, and should we be worried about it?

Dr. WOODSON. Certainly the solar-powered calculators that you buy are generally of Pacific Rim manufacture these days. I do believe that this country should maintain a vigorous R&D program in the solar area, and I do agree with Dr. Jud Howrey that it is in many ways more of an industry problem than it is a basic research and university problem.

For example, at EPRI, they have been working with industry, first of all, to develop a cell with high enough efficiency that it has a chance of being more economically competitive, and then they actually work with a small company to develop the manufacturing process, to try to be able to manufacture the solar cells at low enough cost that this would even enhance things further.

And so they have been attacking the problem at exactly where the bottlenecks are to get it more attractive for use. And that needs to go. That needs to be supported, and I think wherever there is a really good idea for advancing the technology, it ought to be supported.

Mr. SKAGGS. Let me switch just for one last question to a different subject. Dr. Woodson, I may have misheard you in your discussion on nuclear, in essentially saying we may need a long-term isolation strategy in dealing with high- level wastes, which carried the implication that we may not.

I am just wondering if you could correct me if my hearing was wrong, or if it was not, explain what the implication was.

Dr. WOODSON. I think it is clear that we definitely will need geological isolation for a period of time. But as I examine the future and sort of imagine a world in which the rest of the world wants a lot more energy, and there are maybe atmospheric problems that inhibit the burning of fossil fuels, we may get to a day where we have very large- scale and very widespread use of fission energy. And I guess I have trouble imagining that we go on burying ever-increasing amounts of radiological waste in geological formations endlessly, forever.

I think that in time, it would add up to enough that we probably would prefer not to do it that way. And I believe that we live in a society which is headed towards more and more recycling of everything. And I can imagine the day when we develop the technology to essentially render the radioactive waste nonradioactive and nontoxic so that you do not have to isolate it like you do now.

Now, what do you have to do to do that? Well, the radioactive bad actors occur in the waste in very small concentrations, so in order to separate them out so you can work on them, you have to do chemical and physical separation with a precision far beyond what we are capable of now. But it is not impossible. I think it can be developed, and I think we ought to be doing work on such things.

Now, once you have separated out the bad actors and you have concentrated them, you may even find that some of them have commercial value. You may not want to get rid of them. You may want to use them for some purpose. But for the ones you do want to get rid of, you can bombard them with neutrons, energetic neutrons of the right energy, and you can transmute them to other elements. If you keep banging away at them long enough, you can probably make helium out of all of them, and helium is not very dangerous.

So anyway, you can actually render them nonradioactive and nontoxic, in which case then you do not have to go bury them. And I have an idea that over the real long term—and I do not know whether this is 100 years or 200 years or 500 years—the world is still going to be using fission energy but it is not going to want to bury the waste in geological formations and it will develop a way of deactivating the waste. And that is what I was really referring to.

I think we should do research on that to hasten the day that we can actually recycle it, because we are getting to the point where we recycle everything else. We do not want to throw away things that may in time endanger anybody, and I think we should look to recycling our radioactive waste.

Mr. SKAGGS. An interesting view. Maybe we can use some of the extra neutrons from cold fusion to get to work on that.

Dr. WOODSON. Exactly. That may be the first application of fusion, by the way.

Mr. SKAGGS. Thank you, Mr. Chairman.

The CHAIRMAN. Any further questions? The gentleman from Pennsylvania, Mr. Ritter.

Mr. RITTER. I thank the Chairman and I really want to apologize to our witnesses. I was ranking member on a markup of a bill, and

that markup just ended. I apologize to the chairman as well for not being here.

In looking at your testimony, Dr. Chaudhari, you talked about the hot areas, potential breakthrough areas of materials research, the fabrication, the gigabit chip, the gallium arsenide microprocessor, magnesium graphite composite, a wire made of high-temperature superconductors. You could probably add photonic devices, fast and packed for future computers, opto-electronic devices.

In looking at the overall research and development investment of the Federal government, are we investing sufficiently in here? In these areas, have we got our priorities right in the federal R&D economy from your perspective?

Dr. CHAUDHARI. If I had to change things around as far it relates to materials research, I would say that we would pay considerable more emphasis into what I would call synthesis and processing, that is, the making of materials, whether they be for optical electronics or whether they be for megabit chip or a gigabit chip.

I think we need to pay a lot more attention than we have done to that area both at the level of teaching students so they grow up with that in mind, as well as simply increasing the research base. That is an area that we have not emphasized as much as we have other areas of research.

So if I had to pick one, I would pick that one and pay a great deal of attention to it.

Mr. RITTER. The manufacturing, processing aspects.

Dr. CHAUDHARI. Yes. All the way from synthesis of new materials which could lead to new phenomena or new discoveries, to intelligent processing of steel, intelligent processing of metals.

Mr. RITTER. These are relatively applied subjects, are they not?

Dr. CHAUDHARI. Not really. They have always been considered applied and therefore ignored by the university community because they were not intellectually exciting. But I think that you can see that if you are trying to make a new material, a totally new structure whose properties you do not know but you can calculate, then you need to bring together atoms of different kinds to slowly build this.

Now, that same know-how carries over into building an integrated chip. So there is a relationship there between the base of knowledge you generate and the future technologies you bring in. But the interest at that end is purely scientific. How can you devise a structure that will give you a room temperature superconductor, for example? There you have to put atoms in place precisely where you want them and the kinds of atoms you want.

On the other extreme, you are trying to process a slab and you would like to make sure you do this in a very economic way. There the challenge is how do you bring instrumentation on line in a real sense, dynamic way, so you can modify the process as you manufacture it.

Mr. RITTER. But is it not true that we have, to some extent, ignored that side of the coin in our overall federal R&D economy?

Dr. CHAUDHARI. Yes.

Mr. RITTER. We have gone towards the things that the university professors do think are exciting, that is intellectual activities, but

not towards the actual making of things and making them better faster, more effective.

Is that a rational analysis?

Dr. CHAUDHARI. I think the spirit you are conveying is the right one. I would have used perhaps different words.

Mr. RITTER. What would your words be?

Dr. CHAUDHARI. My words would have been that we have not tended to emphasize science or basic engineering in areas that relate to, say, processing of material; the underlying science and engineering of how do you process something, how do you approach it? What approach do you take?

There is a great deal of intellectual depth involved—I think Ralph Gomory touched on it in his testimony—when you are trying to manufacture something. You have to think about the fact that you are trying to manufacture something, design things into it. In materials you have to do the same thing. You are trying to make a slab.

Mr. RITTER. Can we come to a conclusion from Dr. Gomory's testimony and your testimony and some of the things we—of course, you were not here for Rustum Roy's testimony yesterday—but can we come to the conclusion that somehow our priorities are in the more basic side of the science regardless of what we do with that science? Whereas what you are saying is we need to get more involved in what we're doing with it, how we do it, how we apply it, how we use it to accelerate the product cycle.

Could that be said generically, not just for materials but for many of the areas in which, for example, on our side, on the federal research support side that we are active in?

Dr. CHAUDHARI. I would say yes. I think you can generalize that if you look not so much in terms of priorities, I would say that we have a very healthy program in science in the United States and we do very well in that. And then you sort of ask yourself, well, there is science, there is manufacturing at this end, there are a great deal of things in between that have to be developed; do we do as well there? And the answer there is no.

And so you ask yourself, what do you have to do? And I think we have to say, in the case of materials research, that means emphasizing synthesis and processing. That bridges the gap between the two extremes.

Mr. RITTER. If our budgets are flat, for example, in that area of materials and processing and bringing solid state on line faster in the sense we know what to do with these discoveries more quickly and more effectively, if that is flat and/or relatively stable and there are other areas which are growing, would you see that as an imbalance?

I'm going to get right to the point. Should we be investing $10 billion over 10 years in basic high-energy physics matters at this time, or should we take some of that if we have it to invest in the elements that accelerate the product cycle, that bring us back whole on processing and manufacturing and the science and technology base of that? Can you answer that question from your own point of view, not even reflecting IBM's point of view?

Dr. CHAUDHARI. Yes. In fact, I am really answering all your questions from my own point of view. If they happen to agree with IBM's, I think that is great. But they are really my points of view.

If I do not give you a precise answer on that, just correct me. Let me try to address it the following way. The programs, when we talk about the superconducting collider, really have a very different motivation in mind, the scientists who come asking for money for that. When you talk about materials research, you have a very different motivation, and comparing the two is like apples and oranges. I think we have to recognize that.

The motivation for materials research is really very much intimately connected with day-to-day competition of industry. What do you do, how do you make a better product? How does the knowledge you generate translate to this particular thing that I am using?

On the other hand, the superconducting collider is somewhat a greater part of man's dream to understand what is this world all about? I think that is a decision that is best made by you, not by a researcher.

I can tell you the value of this and I can tell you why I would like to see that, because that is really part of my dream to understand what it is all about. But here I understand if I can make a gigabit chip, I can sell it and beat everybody else in the market.

Mr. RITTER. Let me ask you this. In those two fields, where is America hurting most? Are we hurting most in being lax in the understanding of things in the basic science, or are we hurting most on the forefront?

Dr. CHAUDHARI. I would say we are not hurting so much in the basic understanding or science area. Where we are hurting is in being able to translate that scientific knowledge into something that is useful to the man on the street, and that is the way I would summarize it.

I think we are at par and very often the leader in the area of basic science, new discoveries, new phenomena, new materials. But somehow when we take that knowledge very often and translate it year after year, we tend to lose out. So that's the area that I think is important to pay attention to.

Mr. RITTER. Thank you, Dr. Chaudhari. Thank you, Mr. Chairman.

The CHAIRMAN. I thank the gentleman. Are there any further questions? If not, we want to thank you both very much for being with us. Sorry for the delay, but your testimony has been very helpful to the committee and we appreciate your taking your time to be with us today.

Our last two witnesses for today on the role of the American colleges and universities, Dr. Saul K. Fenster, President of the New Jersey Institute of Technology; and Dr. Arnold Speert, President of William Paterson College of New Jersey.

Dr. Fenster, do you want to start? Both your statements will be placed in full in the record. I know you have to catch a plane, so if you want to summarize it is okay, and your statements will appear in full.

[The biographical sketch of Dr. Fenster follows:]

SAUL K. FENSTER

Saul K. Fenster is the sixth President of New Jersey Institute of Technology, the State's comprehensive, technological university. Prior to joining NJIT in 1978, he served in various faculty and administrative capacities at Fairleigh Dickinson University, including six years as Provost of the Rutherford campus.

Dr. Fenster is a Mechanical Engineer. He earned a Bachelors Degree from the City College of New York, a Masters Degree from Columbia University and a Ph.D. from the University of Michigan. He has authored or co-authored two textbooks and numerous research papers and technical articles. His industrial experience includes a period as Senior and Research Engineer with the Sperry Rand Corporation and as a partner in an industrial consulting firm.

Dr. Fenster has served on many statewide task forces, commissions and committees since making New Jersey his home in 1963. His past assignments include the Hudson River Waterfront Study and Planning Commission; the Task Force on Educational Accountability; the Governor's Citizens Task Force on Water Management Emergency which he chaired; the Governor's Commission on Science and Technology; the New Jersey Water Supply Commission on which he was Vice Chair; the Board of Directors of the Southern New Jersey Technology Consortium; and various committees of the American Association of State Colleges and Universities.

He is currently a member of the New Jersey Commission on Science and Technology; the Board of Directors of the Regional Plan Association, the New Jersey State Chamber of Commerce, The Greater Newark Chamber of Commerce, the New Jersey Alliance for Action, the New Jersey Association of Colleges and Universities and the National Action Council for Minorities in Engineering; the Board of Trustees of the New Jersey Sci-Tech Center, Fund for Educational Advancement, and the Public Affairs Research Institute of New Jersey. He is past Chair of the Newark Collaboration Group and a current member of its Executive Committee.

He is a Fellow of the American Society of Mechanical Engineers, and a member of the American Society for Engineering Education, the American Association for the Advancement of Science, the Society of Manufacturing Engineers, and the Council on Competitiveness.

3/89

STATEMENT OF DR. SAUL K. FENSTER, PRESIDENT, NEW JERSEY INSTITUTE OF TECHNOLOGY, NEWARK, NEW JERSEY.

Dr. FENSTER. Thank you very much, Mr. Chairman. I very much enjoy the opportunity of speaking before the committee today. I welcome it. There is some frustration in hearing all these marvelous presentations and wanting to comment on them.

The CHAIRMAN. Well, you can.

Dr. FENSTER. The remark made about manufacturing, for example. At our university, at New Jersey Institute of Technology, we are making a massive investment, our largest investment ever, I suspect, in manufacturing.

And the remark made by one of the committee members I think is quite accurate. Manufacturing in the United States has in fact held at roughly 20 percent of the gross national product for a very long time. I think what we sometimes confuse is manufacturing product on the one hand and manufacturing employment on the other hand. And there is an analog, I believe, between manufacturing and agriculture in that agriculture, as a part of the work force, has dropped I guess from 1900 and before to a very small percentage of our total working population. But agricultural product is still very robust in this country.

Moreover, I do not remember the number, but if you total up all those engaged in manufacturing agricultural product—farmers, processors of food, packagers, distributors, restaurants, chefs, advertisers, marketers, and the rest, exporters of food—it turns out that you have a very, very substantial part of the American economy.

In the manufacturing sector I think you can draw the analog that there are people engaged in derivative businesses which contribute mightily to the U.S. economy. Perhaps fewer and fewer people will be in manufacturing, in making goods per se, because of automation.

And it is the same in fusion of technology which went into agriculture that reduced the number of people who have to grow corn. The same thing is happening in manufacturing. So I quite agree with the premise that we will not simply become a 100 percent service economy. I think that would be a tragic assumption and a tragic conclusion, because we would be totally dependent upon the rest of the world for goods.

Getting to the assigned topic, Mr. Chairman, in terms of the role of universities, I think the whole subject of discussion in this very important series of hearings can be described as a sort of a seamless web between kindergarten on the one hand, research and development somewhere along the line, product manufactured and wealth produced. There is a great number of linkages here, and I will give you an example.

At NJIT we have a very large precollegiate program. Dr. Speert at Paterson, as you know, has a large precollegiate program. We also have this year ranked tenth in the United States in the graduation rate of Black and Hispanic engineers. There is a connection between the two. With each year, our precollege program—now we've been in the business of precollegiate education for almost 20 years and with each year we go down a few grades. We started at

Grade 9, then we went to Grade 7, and now we even have some programs at Grade 4. Mr. Chairman, if I had my druthers in funding, I would go to Grade K as early as possible to get students thinking about science, technology, architecture, management, environmental sorts of stuff in order to encourage them, particularly where they lack role models.

In New Jersey, we have a very active educational opportunity fund program that takes disadvantaged youngsters and it moves them from the collegiate days on. This is back to the seamless web, picking them up perhaps at kindergarten and then helping them through remediation programs where there are no role models, where they are products of some of the less effective school systems.

I think that colleges and universities have a very, very important role to play in R&D, if you will, and I am talking about precollegiate education. In research and development—and I am speaking about making much robust efforts in the areas of bringing minorities into the under-represented work stream, in engineering and science and mathematics, in management, in architecture, in computer science and the like.

And you have already had presentations, as I understand it, in the demographics so I need not talk about the year 2000 which brings with it some real apprehension.

An interesting sidelight with respect to the State of New Jersey, I think should be noted. I read somewhere, and I can not remember the reference, that one of the reasons perhaps the New Jersey economy is starting to show some signs of slowdown—I am not talking about recession, I am talking about just slowing down—is perhaps related to the fact that we have only a 3 percent unemployment rate, which is tantamount to a negative unemployment rate. Perhaps we are starting to run out of human resources which fuel the New Jersey economy. And just perhaps, this is a sort of a precursor of what the year 2000 looks like if we do not have adequate numbers of engineers, scientists, and the like.

Mr. Chairman, as you well know, we have entered a new era of international competition. As recently as 1960, only 20 percent of U.S. produced goods were in active competition with foreign products. But by 1980, this had increased to 70 percent. And presumably the number continues to decline.

Higher order skills is what we need to develop out of the work force. Out of the schools, we must become a nation of people who can think for a living, and we have found, unfortunately, that at this juncture in our history, our public schools, with notable exceptions, are not producing sufficient numbers of well-educated graduates prepared to lead in the future.

I will not dwell upon the condition of the schools. You have heard and read a good deal about this. But I do believe we need more than just a tinkering with the system. It seems to me we need something more dramatic, and one of the more dramatic aspects of what might be recommended is a much keener interest on the part of the colleges and the universities in what is happening in the schools, a much more active intervention. I know that is not the right word. Probably it is "interest and participation" rather than "intervention," which sounds like intrusion. But until the

schools do come up to snuff, the colleges and universities can play a very important role, particularly through precollegiate education.

We have a lack of interest on the part of students engaging in studies in engineering and science. Just one figure: not only are our students avoiding the study of science at the high school level, but more than 40 percent of the students who enter college intending to major in science, are dropping science before they complete their second year of college studies.

Freshman interest in science majors has declined by more than a third in the last 20 years. And yet the employment of scientists and engineers is increasing significantly faster than the total U.S. employment, a very serious situation.

Another serious problem in which there can be significant federal intervention: science and engineering equipment and facilities throughout our educational system and in particular at our undergraduate institutions are increasingly outdated. There has been a federal response, but in my view it has not been adequate to the need. During the past 20 years, federal funding for plant and facilities has declined, I believe the number is by some 95 percent in real terms. Of course, many of our colleagues are frustrated by the inadequacy of federal funding in this area, particularly feeling, as many of them do, that most of the funding is available to the heavily engaged research universities rather than the principally undergraduate institutions.

What role should America's colleges and universities play as the nation prepares for the global economy of the 1990s and the year 2000? There are four principal roles:

1. Prepare, obviously, a professional scientific and engineering work force capable of giving America edge.

2. Conduct basic research—and we have talked about that—which will be a foundation for emerging fields such as biotechnology, photonics, opto-electronics, fifth generation computing, superconductivity, fiber optics, ceramics, advanced surfaced engineered materials, and in the development of new approaches for protecting and restoring the environment.

Just to refer back to what Dean Woodson said, if we cannot deal effectively with the product of our civilization—the industrial wastestream and the garbage that we produce, and we cannot recycle effectively to reduce that product, to minimize the volume and to deal with the energy needs—that will be a deterrent to economic development. That is in some places a deterrent to economic development. We know in our state, Mr. Chairman, that it ss a deterrent to economic development.

So dealing with hazardous and substance waste management, with solid waste management, and dealing in a way which is environmentally responsible, and at the same time encouraging industries to move into geographic areas which have a rational response to these problems, that is a very important field for university research.

I am going back to the issue of whether university research is only directed to the esoteric, to the pure and so on. More and more engineering-oriented institutions are becoming involved in applied research with close corporate allies and with close government allies. And that is part of that seamless web: the universities, gov-

ernment, the corporate community, and going back to grade schools, precollegiate programs, programs for high school teachers and the like.

3. A third aspect: Provide technical assistance—this is in the role of colleges and universities—provide technical assistance to the public, private and nonprofit sectors in implementing the new technologies. And, of course, in New Jersey we have a Commission on Science and Technology which helps us to fund advanced technology centers, technology transfer centers, and to stimulate innovation through innovation partnerships. I will not dwell on that.

4. And, finally, serve as a catalyst for the formation of new partnerships among government, industry and academe.

I wanted very quickly to give an example of this because I think this is a good model. It may not be unique, but I don't think it's duplicated in too many places. NJIT is the lead institution in a Hazardous Substance Management Research Center, a consortium with Princeton, Rutgers, Stevens, and the University of Medicine and Dentistry in New Jersey. HSMRC, as we call it, is supported by the New Jersey Science and Technology Commission, the National Science Foundation, and 28 corporations and public agencies.

HSMRC identifies environmentally acceptable, economically viable hazardous waste treatment technologies and facilitates the exchange of ideas among industry, government, academe, and the public. And the university serves the role not only of conducting the research, but serving as the level playing field, the non-ideological playing field.

The Center has undertaken 101 projects since its founding in 1984. Over 50 faculty members are involved. A major research objective is the evaluation and improvement of emerging technologies in hazardous substance management. And I will not go through all of the manifestations of those subjects: air, water, pollution, site assessment, soil contamination and the like.

Very recently, HSMRC has become a federal EPA center for Regions I and II, as you know, Mr. Chairman, with NJIT in lead, involving a consortium of MIT, Princeton, Rutgers, Stevens, Tufts and the University of Medicine and Dentistry. You cannot get a more complicated structural organization. Twenty-eight corporations, more than half a dozen universities, federal government and state government. And yet, despite all of that complexity, it works, it produces practical solutions. Much of the research agenda is in fact recommended strongly by the corporations.

Just a few final notes. I wanted to mention the potential shortage of PhDs, and Dean Woodson touched upon the future problem that we have. At yesterday's hearings at the New Jersey Senate Appropriations Committee, the issue arose as well about the number of non-U.S. nationals studying in our graduate programs, and I just wanted to touch upon this.

A future shortage of U.S. engineers was highlighted in the 1988 National Research Council Report. The Council pointed out that the number of engineers who are not U.S. nationals was increasing not only in American industry, where almost one out of three doctorate engineers is a non- U.S. national, but also in academe. In 1985, almost half of the assistant professors, almost half of the assistant professors under the age of 35 in U.S. engineering schools

were foreign-born. And foreign-born engineers make up 60 percent of all students earning PhDs in U.S. engineering schools.

Now, the danger here is not so much that there are this many non-U.S. nationals studying in our graduate schools because, as it turns out, many of these, in fact in New Jersey most of these individuals remain in the country and contribute to R&D and to our faculties. This is very positive and in fact we have found that the rest of the world has in fact picked up the slack where we have failed in this country to produce appropriate numbers of U.S. national engineers and scientists.

The problem or the danger here is that a strategic element of our economy is dependent upon factors which are in fact controlled by other nations. And if other nations change their policies, we will be caught very, very short. We talked about, I think earlier Dean Woodson talked about a shortage of 7,500—I do not remember what the precise number is—but a specific recommendation that we can make in dealing with this problem is that—and this is not an original thought on my part—is that what we need to do is have a graduate student fellowship program which provides four years of study to numbers of around 3,000 students each year, providing about $25,000 per student. That would be the kind of number, $25,000, which could inspire a youngster with a baccalaureate degree, U.S. national, to remain and pursue the masters and doctoral degree in a United States university and think about a career on a faculty or in an industrial setting.

Given the lateness of the hour, Mr. Chairman, I will conclude my remarks with the comment that a good deal of the future R&D needs of the nation and a good deal of the current R&D needs of the nation are being picked up in very unique creative ways by our colleges and universities. They do need more help and equipment, equipment of laboratories. They need help in fellowships, particularly for graduate students. They need to participate much more aggressively and actively in the precollegiate programs, programs that hitherto were reserved to primary and secondary schools. I do not think that the response of the primary and secondary schools has been adequate to the task. It is important for the good of the nation and for the good of the colleges and universities to step in until that problem is dealt with effectively elsewhere.

Thank you very much for your kind attention, Mr. Chairman.

[The prepared statement of Dr. Saul K. Fenster follows.]

TESTIMONY BEFORE THE

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

APRIL 12, 1989

by

SAUL K. FENSTER
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Mr. Chairman and members of the Committee:

Thank you for the opportunity to speak to you today

You have invited me to speak about the role of America's colleges and universities in contributing to the generation of new scientific and engineering knowledge and how these institutions can work in partnership with industry and government. I will focus the major part of my remarks on higher education and innovative partnerships with industry and government.

I must begin by emphasizing that the entire educational enterprise, from kindergarten to postgraduate studies is interconnected. We cannot plan for higher education without relating those plans to primary and secondary education. In fact, many of the problems which we face in higher education have their origins at other levels of education, in the home or in the community. To maximize efforts to strengthen higher education, we must also address the problems and needs of primary and secondary schools. Let me give you one example based upon our experience at New Jersey Institute of Technology. In August, 1988, the National Action Council for Minorities in Engineering ranked NJIT as tenth in the nation in graduating baccalaureate degree minority engineers. This accomplishment was made possible not only because of a wide array of programs at the collegiate level but also by a comprehensive Pre-

College program. Nearly two decades of involvement in pre-college science and engineering programs have convinced NJIT that the greatest success in assisting minority students results from intervention beginning in the fourth grade or even earlier, if possible. For that reason, in recent years, NJIT has focused on serving increasingly younger students. Of course the minority engineers graduating depend just as importantly upon a freshman program for educationally and economically disadvantaged students, supported by the state, and a transfer program from the state's community colleges.

Mr. Chairman, as you well know, we have entered a new era of international competition. As recently as 1960, only 20% of U.S. produced goods were in active competition with foreign products. By 1980, this had increased to 70%, and presumably the number continues to climb. To remain competitive, we must develop new technologies, design new products and implement new processes at an ever increasing pace. This requires a workforce with new skills and knowledge. Higher order skills such as the ability to absorb and process complex information, solve problems and express ideas with precision are essential. According to Marc S. Tucker, President of the National Center on Education and the Economy, "We must become a nation of people who can think for a living."

Unfortunately, at this critical juncture in the history of our nation, our public schools, with notable exceptions, are not producing sufficient number of well educated graduates, prepared to lead America into the future. I will not dwell on the condition of

America's public schools. Numerous governmental commissions, private foundations and the media already have described the dimensions of the crisis we face. I do wish to commend the Public Broadcasting System (PBS) for its current series "Learning In America" and the Wall Street Journal for its March 31, 1989, education report "Retooling The Schools." PBS and the Wall Street Journal suggest that the American educational system needs a complete overhaul, not just tinkering or fine tuning. I agree.

Our nation faces a real threat of economic failure and a lower quality of life unless - as a nation - we commit ourselves to a dramatic increase in the quality of our educational system. Today, I want to emphasize to this distinguished committee that our nation must commit itself to increasing the number and quality of students choosing to study science, mathematics and engineering. All indicators show that the pool of science and engineering students is decreasing. Not only are students avoiding the study of science at the high school level, but more than 40% of the students who enter college intending to major in science are dropping science before they complete their second year of college studies.

Let me highlight another serious problem. Science and engineering equipment and facilities throughout our educational system and, in particular, at undergraduate institutions are increasingly outdated. The Federal response to this crisis has fallen far short of the need. Many of my colleagues are frustrated by the inadequacy of Federal funding to address these equipment and facilities needs

and by the impression that what Federal funding is available is heavily directed to the larger research universities.

Mr. Chairman, we in the academic community are aware that this is not a time for just asking Congress for more money. This is a time in which every American must accept responsibility to do his or her part and to do it well - with pride and excellence. This is a time in which we must hold one another accountable. We know that this process of responsibility and accountability begins not with money but with parents and teachers instilling a love of learning in children.

We also realize that Federal deficits and increasing costs will force us to try to do more with less. As I speak with my colleagues across the country, some are beginning to wonder if we are now "running out of less."

What role should America's colleges and universities play as the nation prepares for the global economy of the 1990's and the twenty-first century?

Most colleges and universities have a threefold mission of instruction, research and service. The service mission often affords institutions an opportunity to use science and technology to analyze and solve problems affecting the quality of life and the economic base of their

communities and nation. To assure a high quality of life and economic success American colleges and universities must:

1. Prepare a professional, scientific and engineering workforce capable of giving America a competitive edge;

2. Conduct basic research which will be a foundation for emerging fields such as biotechnology, photonics, opto-electronics, fifth generation computing, superconductivity, fiber optics, ceramics, advanced surfaced engineered materials, and in developing new approaches for protecting and restoring the environment.

3. Provide technical assistance to the public, private and non-profit sectors in implementing new technologies. New Jersey with the support of state government and in particular the state Commission on Science and Technology, has established a number of successful technology transfer programs in areas such as those in polymer processing, computer and information services, fishing and agriculture, transportation and medicine. One program assists hospitals throughout New Jersey in adopting advanced cancer diagnostic and therapeutic techniques that formerly were available only in major university teaching hospitals.

4. Serve as the catalyst for the formation of new partnerships among government, industry and academe. These partnerships bring together universities which excel in research, with

government and industry focusing on the application of science and technology to specific issues and problems. As such, these partnerships hold the potential of helping America make more effective use of national resources in closing the gap between the development and implementation of new technologies. Closing that gap is one of the nation's best "windows of opportunity" in a global economy.

At NJIT we have been successful in developing a number of these government, industry, and university partnerships in areas such as the management of hazardous substances, opto-electronics, microwave and lightwave engineering, computerized conferencing and manufacturing.

One of these initiatives is a model for how a university can serve as the neutral but yet catalytic ground on which an energetic alliance of government, industry and the university can advance science and technology, support economic well-being, and, at the same time serve society.

NJIT is the lead institution in the Hazardous Substance Management Research Center (HSMRC), a consortium with Princeton University, Rutgers University, Stevens Institute of Technology and the University of Medicine and Dentistry of New Jersey. HSMRC is supported by the New Jersey Commission on Science and Technology, the National Science Foundation and twenty-eight corporations and public agencies. HSMRC identifies effective,

environmentally acceptable, economically viable hazardous waste treatment technologies and also facilitates the exchange of ideas and knowledge among industry, government, academe and the public. The Center has undertaken 101 projects since its founding in 1984. A major research objective is the evaluation and improvement of emerging technologies in hazardous substance management including the engineering design of systems for treatment of hazardous industrial waste streams, development of biological techniques for waste treatment, and dispersion modeling of pollutants in air, water and soils. Major points to be made are that effective hazardous substance management encourages industrial growth and development, and helps to create new businesses specializing in the environmental field. To ignore this environmental area is to limit economic growth.

In large part, as the result of the success of HSMRC, the U.S. Environmental Protection Agency (EPA) has selected NJIT as the lead institution in a consortium for hazardous substance research for the Federal Regions 1 and 2. Other university members in the consortium are Massachusetts Institute of Technology, Princeton University, Rutgers University, Stevens Institute of Technology, Tufts University and the University of Medicine and Dentistry of New Jersey. The consortium will conduct long and short-term research on the manufacture, use, transportation, disposal and management of hazardous substances. In the first year, the research will focus on such areas as groundwater remediation, soil decontamination, incineration and transportation. In addition, the Center will provide training, technology transfer and technical support.

America's Colleges and Universities
Need Additional Support From the Federal Government

American industry tends to expect research and development to begin paying dividends within a three to five year timeframe. In contrast, Japanese industry, with governmental support, provides for up to a 15 year timeframe for profitability. This longer term approach gives Japanese industry a distinct advantage in the implementation of new technologies.

To develop new products and processes in a technology dependent economy, America must invest more resources in basic research and adopt a longer term approach to research and development. Colleges and universities are an ideal place for basic and applied research to be conducted. This is not a new concept. Throughout our history, colleges and universities have played a major role in conducting research and many great commercial successes have been the result of the research conducted at American colleges and universities.

It is vitally important that the Federal government increase financial support for college and university based research. But the critically significant outcome of such research is probably more the education of students than the creation of new knowledge. Today's student researchers hold the potential to be tomorrow's masters. We

must provide the resources for promising students to conduct research under the mentorship of distinguished faculty. This translates into the need for increased Federal support for students, faculty, equipment and facilities. Failure to provide increased scholarships and low interest loans for undergraduates and increased fellowships and low interest loans for graduate students would be short sighted. We have no alternative but to invest in our future and our future depends on having an adequate supply of scientists, engineers and people who can manage technology.

A future shortage of U.S. engineers was highlighted in a 1988 National Research Council report. The Council pointed out that the number of engineers who are not U.S. nationals was increasing not only in American industry (almost one out of three doctorate engineers employed in industry - and that number is increasing) but also in academe. In 1985, almost half of the assistant professors under the age of 35 in U.S. engineering schools were foreign born and foreign-born engineers make up 60% of all students earning Ph.Ds in U.S. engineering schools. The danger here is that a strategic element of our economy is dependent upon factors controlled by other nations.

While the number of foreign-born graduate engineering students is growing, the number of U.S. born engineering Ph.D. candidates has fallen sharply. There are a number of public policy and social value causes for this decline. Among the most important is the reduction in the number of graduate fellowships available only to U.S. citizens.

To encourage American engineers to enter doctoral programs we must engage both short and long term strategies. In the short term, we must pay adequate stipends. Doctoral students have a difficult time surviving on current stipends, particularly if their university is in a high-cost area. In the long term, we must improve the image of engineers and scientists. They are needed to build our future, to create new tools, to solve the problems facing the nation. Through their work, engineers and scientists benefit the human family and create new wealth. We must encourage more of our children to enter these professions and to dedicate themselves as teachers of others.

THANK YOU MR. CHAIRMAN

The CHAIRMAN. Thank you very much, Dr. Fenster.
How about Dr. Speert now?
[The biographical sketch of Dr. Speert follows:]

ARNOLD SPEERT

Dr. Arnold Speert became the sixth president of William Paterson College on September 1, 1985. He ascended from the post of vice president for academic affairs, which he had held since July, 1979.

In 1970 he joined the college teaching staff as an assistant professor of chemistry and later that same year assumed his initial administrative responsibilities as assistant to the dean of graduate and research programs. Dr. Speert was named assistant to the vice president for academic affairs in 1971 and became associate dean for academic affairs in 1978. During the same period he rose through the faculty ranks to full professor in 1980.

While he was academic vice president, he served as chief executive officer of WPC during former President Seymour C. Hyman's sabbatical leave, January 1984 through April 1984. He was chairman of the New Jersey State College Council of Academic Vice Presidents from 1983-85.

A Phi Beta Kappa at The City College of The City University of New York, Dr. Speert graduated cum laude with honors in chemistry. He received the New York State Regents Scholarship and was listed in Who's Who Among Students in American Universities and Colleges.

Dr. Speert earned his Ph.D. in chemistry from Princeton University where he was a National Institutes of Health Fellow. Elected to Sigma Xi, he was also a New York State Regents College Teaching Fellow.

Major areas of research and publication for Dr. Speert are subjects related to spectroscopy, London-van der Waals forces and bond fixation. He is a member of

the American Chemical Society, The Royal Society of Chemistry and The American Association for the Advancement of Science.

Active in the community, Dr. Speert is a director of the Broadway Bank and Trust Company and of the Greater Wayne Chamber of Commerce. He is a trustee of Barnert Hospital, the North Jersey Jewish Federation and The William Paterson College Foundation. He also serves on the Board of Examiners of the New Jersey State Department of Education. While a Jefferson Township, New Jersey resident, Dr. Speert served as a member of the township's Environmental Commission and its Water Advisory Board.

Dr. Speert, his wife Myrna, a high school mathematics teacher, and their children, Alan and Debra, occupy the college president's official residence in Wayne.

3/88

STATEMENT OF DR. ARNOLD SPEERT, PRESIDENT, WILLIAM PATERSON COLLEGE, AND REPRESENTING AMERICAN ASSOCIATION OF STATE COLLEGES AND UNIVERSITIES, WAYNE, NEW JERSEY.

Dr. SPEERT. It was a pleasure hearing the attention given to the education community both by the committee and by my colleague and by prior speakers to the role we can play in creating the new wealth.

It is indeed a pleasure to appear before you, Mr. Chairman, on behalf of the 372 members of the American Association of State Colleges and Universities. The challenge for today is how we can ensure a skilled and technologically literature workforce for the 21st century. This is an enormous challenge, demanding action at all levels of education from preschool to the graduate university.

Comprehensive colleges and universities will take a leadership role in this endeavor. Rooted in the tradition of teacher training, our commitment to the educational process at all levels is unbending. We produce over 50 percent of the K through 12 teachers, significant numbers of students for our nation's graduate and professional schools, and a large percentage of the professional work force.

Comprehensive colleges and universities are playing a pivotal role in the improvement of science and mathematics education. William Paterson College provides a model of how such institutions can and should contribute. In 1986 the College received a $4.5 million Challenge to Excellence Grant from the State of New Jersey to establish Centers of Excellence in telecommunications and science.

The telecommunications initiative, utilizing our campus's natural geographic advantage, will establish the College as a communications gateway worldwide for educational institutions in northern New Jersey.

More germane to this discussion, however, is the science initiative. William Paterson College is spending $3.1 million of our Challenge Grant to improve science and mathematics education, focusing on six major themes:

1. Acquisition of state-of-the-art instrumentation. This investment of $1.7 million ensures that our graduates will have hands-on experience with the types of instrumentation they will encounter in the workplace or graduate school, including a nuclear magnetic resonance spectrometer, DNA sequencer, and scanning electron microscope.

2. Support of faculty research in science and mathematics through summer stipends, release time, travel funds and supplies. This support ensures that our faculty remains current in their discipline, thereby greatly enhancing our teaching program.

For example, our science faculty have given over 40 presentations and scientific meetings around the world in the last two years as compared to less than 20 presentations in the four years prior to the Challenge Grant.

3. Support of undergraduate science research. This support annually provides 25 of our students with the opportunity to work closely with our faculty on their research, providing a transition from

the world of textbook learning to the practical application of that learning.

4. Reinforcing what Dr. Fenster spoke about, precollege science and mathematics education. This support is focused on two groups: science and mathematics teachers and their students. The teachers participate in academic year and summer workshop programs dealing with latest developments in such areas as biotechnology, neurobiology, wetland ecology, and fractile geometry. Through the 125 participating teachers, over 10,000 New Jersey high school students have learned of current and future directions in science and mathematics in the last two years.

The students participate in summer academic programs. One oriented specifically toward minority students with academic promise from nearly urban high schools in Paterson has served 87 students over the last three years. The high school graduation rate among participants who remain in the program is 100 percent, with 28 of 29 attending colleges, including West Point, Notre Dame, Wellesley College, the New Jersey Institute of Technology, Rutgers University, William Paterson College, and seven other New Jersey colleges.

A second program for 200 academically gifted and talented junior high school students from both urban and suburban schools will be launched this summer, with the urging and support of the School of Science and Mathematics Advisory Council of Corporate Executives.

5. Development of new degree programs. New degree programs are being developed in the areas of biotechnology, environmental science, and applied mathematics to meet the changing needs of New Jersey's employers. Our new bachelors/masters degree program in biotechnology, which we expect the State will approve for September 1989 implementation, addresses the New Jersey Commission on Science and Technology's priorities of (1) full development of advanced technology fields, biotechnology among them, and (2) the encouragement of a technologically trained work force to meet employment needs for New Jersey into the 21st century.

The program focusing on recombinant DNA technology will annually graduate approximately 20 baccalaureate and 15 masters students prepared for entry-level technical positions with New Jersey's biotechnology industries, or further study at PhD granting institutions.

6. Public awareness of science. Lectures by such leading scientists as Stephen J. Gould, Robert Peter Gale, and Richard Leakey, combined with theater productions such as "Inherit the Wind" are presented to invited audiences from area public schools and the general public to facilitate public awareness and understanding of science.

Our Challenge Grant has allowed us to address many of the critical short and long-term needs associated with science and mathematics education. It has also pointed to areas where additional support is absolutely essential. In my judgment, these are sixfold:

1. A critical need exists for greater support of teacher training and retraining in the areas of science and mathematics. Districts and teachers often do not have the necessary resources; thus, it is imperative that government, industry, and higher education unite to fund this absolutely essential training.

2. Funding of precollege programs that encourage minorities to enter careers in science and mathematics is essential, given the changing demographics of the United States and the current under-representation of Blacks and Hispanics in these disciplines.

3. Student research and scholarship opportunities must be made available for our brightest undergraduates to encourage pursuit of careers in science and mathematics, ensuring continuation of an adequate supply of scientists and engineers into the 21st century.

4. Sufficient funds must be available to support faculty research at teaching-intensive comprehensive colleges and universities.

5. State-of-the-art instrumentation must be available to undergraduates to properly prepare them for graduate school or the work force.

6. Attention must be given to science laboratory facilities. We highly recommend appropriating funds for the academic research facilities modernization program authorized in P.L. 100-418, which will provide $125 million for these purposes in the first year. At William Paterson College, the science building was designed primarily for teaching, but we are now engaged in a wide variety of research and training activities. We estimate it would require an expenditure of $5 to $6 million to renovate and modernize our science building to adequately accommodate the multitude of programs and initiatives we have undertaken to meet the challenges of the 21st century.

In closing, I thank you for the opportunity to address what I see as urgent needs for science and mathematics education. With your assistance, I am confident that William Paterson College and other AASCU institutions can meet the challenge of providing a skilled and technologically literate work force, ensuring the global competitiveness of the United States into the 21st century and beyond.

[The prepared statement of Dr. Speert follows:]

Testimony of Dr. Arnold Speert, President of The William Paterson College of New Jersey, to the Committee on Science, Space and Technology, 12 April 1989

Chairman Roe and members of the Committee, it is indeed a pleasure to appear before you on behalf of the 372 member American Association of State Colleges and Universities.

Comprehensive colleges and universities have always assumed a leadership role in insuring the global competitiveness of the United States of America. The William Paterson College of New Jersey exemplifies this spirit and tradition as well as any college in the country. The College was founded in 1855 as Paterson City Normal School in response to the growing demand for more competent teaching in the emerging free public schools of this burgeoning industrial city. But times change and the needs of the community change. Following World War II the need for a new kind of college that provided a comprehensive set of major programs beyond teacher education arose. William Paterson College met that challenge for a more highly educated work force, evolving over a 20 year period into a comprehensive institution. During this period the College moved to a new 250 acre suburban campus in Wayne, New Jersey, to accommodate the resultant rapid growth. By 1967 when the State of New Jersey mandated that teachers' colleges be transformed to comprehensive liberal studies institutions, William Paterson College was ready with an array of programs ranging from biology and chemistry to nursing, English, communication, psychology, and management.

The challenge for today is how to insure a skilled and technologically literate work force for the 21st century. This is an enormous challenge demanding action at all levels of education from preschool to the graduate university. The comprehensive colleges and universities will take a leadership role in this endeavor. Rooted in the tradition of teacher training, our commitment to the educational process at all levels is unbending. We produce over 40% of all K-12 teachers, significant numbers of students for our nation's graduate and professional schools, and a large percentage of the professional work force. Comprehensive colleges and universities are playing a pivotal role in the improvement of science and mathematics education.

Once again William Paterson College provides a model of how such institutions can and should contribute. In 1986 the College received a $4.5 million Challenge to Excellence Grant from the State of New Jersey to establish centers of excellence in telecommunications and science. The telecommunications initiative, utilizing our campus' natural geographic advantage, will establish the College as a telecommunications gateway worldwide for educational institutions in northern New Jersey.

More germane to this discussion, however, is the science initiative. William Paterson College is spending $3.1 million of our Challenge Grant to improve science and mathematics education, focusing on six major themes:

1. Acquisition of state-of-the-art instrumentation. This investment of $1.7 million insures our graduates will have hands-on experience with the types of instrumentation they will encounter in the workplace or graduate school, including a nuclear magnetic resonance spectrometer, DNA sequencer, and scanning electron microscope.
2. Support of faculty research in science and mathematics through summer stipends, released time, travel funds, and supplies. This support insures that our faculty remains current in their discipline thereby greatly enhancing our teaching program. For example, our science faculty have given over 40 presentations at scientific meetings around the world in the last two years, as compared to less than 20 presentations in the four years prior to the Challenge Grant.
3. Support of undergraduate science research. This support annually provides 25 of our students with the opportunity to work closely with our faculty on their research, providing a transition from the world of textbook learning to the practical application of that learning.
4. Pre-college science and mathematics education. This support is focused on two groups, science and mathematics teachers and their students. The teachers participate in academic year and summer workshop

programs dealing with the latest developments in such areas as biotechnology, neurobiology, wetland ecology, and fractal geometry. Through the 125 participating teachers, over 10,000 New Jersey high school students have learned of current and future directions in science and mathematics in the last two years. The students participate in summer academic programs. One oriented specifically toward minority students with academic promise from nearby urban high schools in Paterson has served 87 students over the last three years. The high school graduation rate among participants is 100%, with 28 of 29 attending college including West Point, Notre Dame, Wellesley College, New Jersey Institute of Technology, Rutgers University, William Paterson College, and seven other New Jersey colleges. A second program for 200 academically gifted and talented junior high school students from both urban and suburban schools will be launched this summer with the urging and support of the School of Science and Mathematics' Advisory Council of corporate executives.

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1. A critical need exists for greater support of teacher training and retraining in the areas of science and mathematics. Districts and teachers often do not have the necessary resources, thus it is imperative that

government, industry and higher education unite to fund this absolutely essential training.

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3. Student research and scholarship opportunities must be made available for our brightest undergraduates to encourage pursuit of careers in science and mathematics, insuring continuation of an adequate supply of scientists and engineers into the 21st century.
4. Sufficient funds must be available to support faculty research at teaching intensive comprehensive colleges and universities.
5. State-of-the-art instrumentation must be available to undergraduates to properly prepare them for graduate school or the work force.
6. Attention must be given to science laboratory facilities. At William Paterson College, the science building was designed primarily for teaching, but we are now engaged in a wide variety of research and training activities. We estimate it would require an expenditure of $8-10 million to renovate and modernize our science building to adequately accommodate the multitude of programs and initiatives we have undertaken to meet the challenges of the 21st century.

In closing, I thank you for the opportunity to address what I see as urgent needs for science and mathematics education. With your assistance, I am confident that The William Paterson College of New Jersey and other AASCU institutions can meet the challenge of providing a skilled and technologically literate work force, insuring the global competitiveness of the United States of America into the 21st century and beyond.

The CHAIRMAN. I want to thank both of our distinguished representatives from New Jersey.

We have the distinguished gentleman from Tennessee. Do you have any questions you would like to ask? Mr. Tanner.

Mr. TANNER. Thank you very much, Mr. Chairman. I, too, enjoyed your testimony.

Did either one of you gentlemen see the—maybe you were here earlier—"Losing the Future"?

Dr. SPEERT. No, I did not.

Mr. TANNER. It was a special. By way of some background, I went to a science and technology forum at Dyersburg State College, which is in my district in Tennessee, last Friday night. They showed this movie and it blamed but pointed out as well a combination of government, education, and business for what many perceive to be our inability to compete worldwide now, and we have heard testimony this morning about the manufacturing aspect of that.

Which leads me to my question of either or both of you gentlemen. Many people perceive that we are falling behind the rest of the industrialized world in terms of public education. One of the features of this program pointed out that in Japan—that seems to be the focal point of our discussions as it relates to this topic—children attend school some 240 days a year on the average, and in this country 180 days on the average, elementary and secondary schools.

Would either of you address that, particularly Dr. Fenster, when you alluded to the fact that we needed to get more involved from your level in elementary education?

Dr. FENSTER. Yes. I would be very happy to comment on that. In a sense, that is what I was alluding to when I said we need to do more than tinker with the system. If we feel that our youngsters are not being adequately prepared, obviously we need to better prepare our teachers, we need to have better facilities in our primary and secondary schools. But we need to also send a very strong message and a reality to the youngsters and to the teachers that we mean to be very serious about the business of educating.

I would advocate, strongly, extending the school year. There is not anything magical about what we are doing now. We are doing an inadequate job of educating in the allotted school year. We ought to extend it. As you know, the school is an anachronism of an agricultural society, and it no longer is applicable. We have to do some dramatic sorts of things to adequately prepare students.

All of the projections for the year 2000 talk about the level of preparedness required for even routine sorts of careers, tasks, jobs in the year 2000. They talk about two years of college required for X percentage of the jobs. I hope they are not talking about two years of college required because they need someone with a ninth grade education. I hope that is not what the inference is.

But I would support extending the school year, and I think there will be a very heavy price tag in terms of teacher preparation and teacher salary and refurbishing or building, new physical facilities. But I think we are talking about preserving the quality of life and the economic advantages of the United States of America. I think that's what is at stake, and I think that is going to require more

than just a special little program here and a special after-school program given in high school X there. I think it is going to require something very much more comprehensive.

Dr. SPEERT. In fact, many of us have seized upon the summer hiatus to provide precollege programs, both to encourage the students and also to fill a serious gap. I believe that setting a level of expectation high enough for people to grasp toward, rather than being satisfied with the kind of preparation we presently have, is very necessary.

Mr. TANNER. One more question, if I might. There are some people in this country who resist the idea or notion of the federal government becoming involved in public education, believing that it ought to be left to the local school boards and states.

The problem, if some of the observers are to be believed, is getting more and more serious and our students are knowing less and less in the ninth grade or the twelfth grade or whatever.

As we sit here, all recognizing some problem, the degree of which may differ from individual to individual, what do you have or either of you have in terms of recommendation for how we deal with this? Does this need to come from the professional education community? Does it need to come from us here in Congress or from the White House?

Someone has got to step out and take the lead and say, "People, this is a crisis." I do not know who can best do that. What are your ideas there?

Dr. SPEERT. Congressman Tanner, I must tell you that I am biased. I am a product of the Sputnik scare and went to a high school in the City of New York, Bronx High School of Science, which was dedicated toward a response in a sense, but had been a longstanding institution. But it was the impetus from the federal government that spurred on many of the programs.

And I believe this committee in the last few years has taken the leadership role and must continue to take that leadership role, because I think that the direction must come from all sectors of government, encouraging the kinds of development we talk about.

Dr. FENSTER. I would agree with my colleague fully.

Mr. TANNER. How do we make the case for what is going to be most certainly a difficult political decision to put the federal government in the forefront, if that is what we decide has to be done in terms of extending the school year, for example?

Dr. FENSTER. Just a comment on the difficulty. Even where the constitutional role is more clearly assigned to the states, as you know, you have a tradition in many states, as we have, of very strong home rule. And even where the task is clearly in the purview of the state, the local municipalities and school districts can have a monumental effect on impeding the kind of progress that is required. And we see this, notwithstanding efforts made at reform.

Even relatively mild efforts made at reform are thwarted and they are litigated and the like. There has to be very much stronger legislation. I was alluding to this. I know it is intrusive; it is intrusive on the part of the university to get involved in precollegiate education and trying to effect reform in local school districts, and it potentially is intrusive on the part of the federal government to be involved.

But if we are talking about a strategic interest—and I think that is what Dr. Speert was talking about in the case of the 1960s reaction of this country in mobilizing its industry and its educational resources and the Congress and all the rest—if we are talking about a strategic concern, we may just have to be a tad more intrusive than we have been.

Mr. TANNER. I thank the Chair.

The CHAIRMAN. And also considering, what was it, close to 40 percent of our school budgets are voted down locally.

Well, we want to thank you very much. We know you have to catch a 2 o'clock plane, so that your input has been a great help to us.

The Chair is going to recess these hearings for further consideration. Thank you very much.

[Whereupon, at 1:12 p.m. the hearing was adjourned, subject to the call of the Chair.]